Guidance Manual
for
Siting, Design and Maintenance of
Golf Courses in New Jersey

New Jersey Department of

Environmental Protection and Energy

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Chapter 1. Objectives

An appropriate response to the environmental questions concerning the proper design and maintenance of golf courses in New Jersey is long overdue. It is paramount to have proper guidance to minimize and/or prevent adverse environmental impacts of golf courses on the natural resources of the state including surface waters, wildlife, ground waters and water supply resources.

Also, in an attempt to respond to the growing demand for recreation in New Jersey, the New Jersey Department of Environmental Protection and Energy (NJDEPE or Department) has developed this guidance manual for the siting, design, construction and maintenance of golf courses in areas requiring a Coastal Area Facilities Review Act Permit, a Waterfront Development Permit, a Stream Encroachment Permit, and/or a Freshwater Wetland Permit. **This guidance manual is to inform the applicant of the different types of information needed by the Land Use Regulatory Program prior to processing and issuing a permit under their jurisdiction.**

This manual is not intended to serve as a detailed manual for the design and/or maintenance of a golf course. The objectives of this manual are:

- To identify and outline administrative procedures and application requirements when an applicant wishes to construct a golf course in an area requiring a Coastal Area Facilities Review Act Permit, a Waterfront Development Permit, a Stream Encroachment Permit, and/or a Freshwater Wetland Permit;

- To inform the applicant of specific technical, management, and planning information required to be submitted to the Department for review when he/she wishes to construct a golf course in an area requiring any one of the above listed permits. Information to be submitted includes:

I. A Survey Plan
II. A Site Plan
III. Modelling Results
IV. An Environmental Impact Statement
V. Best Management Practices and Pollution Prevention Plans
VI. Pesticides and Fertilizer Application Plans
VII. Surface and Ground Water Monitoring Plans

- To provide general guidelines for the design of a golf course including site selection, restricted areas of development, location of ponds and irrigation wells, and maintenance of undisturbed vegetated buffers adjacent to streams, wetlands, and other waterbodies, etc.;

- To provide guidance for performing pollution impact assessments including modelling to predict water quality impacts;

- To provide strategies for controlling the quality of stormwater runoff;

- To provide guidance for the design of water quality sampling/monitoring programs for surface waterbodies and ground waters at proposed golf course sites;

- To provide guidance for best management practices (BMPs) to minimize environmental impacts stemming from the operation of a golf course;

- To provide guidance for the application of pesticides and fertilizers;

- To provide guidelines as to when remedial actions should be rendered if the impacts on receiving waterbodies and/or ground water are identified; and

- To better co-ordinate, process, and evaluate decisions made in the siting, design, construction and maintenance of golf courses so as to foster the integration of man's activities with the environment by creating eco-friendly golf courses.

Chapter 2. Administrative Procedures

The administrative procedures as shown in Figure II.1 include the following steps: 1) Pre-application conferences; 2) Application package preparation and submittal; 3) NJDEPE review of submitted packet; and 4) permit(s) decision. The Land Use Regulatory Program (LURP) will serve as the initial contact for applicants and will be the coordinator of the review process.

I. Pre-application Conferences

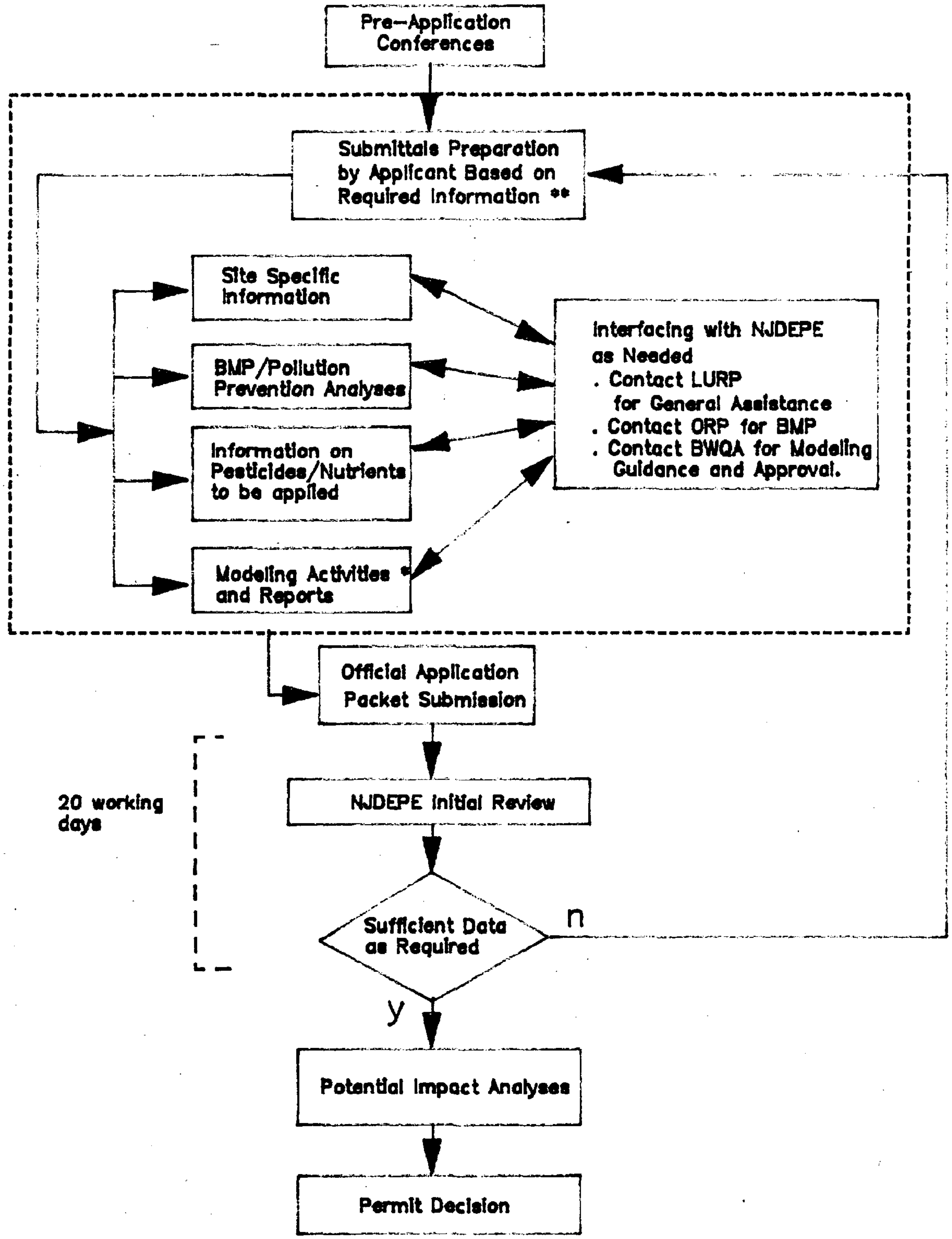
Pre-application conferences are necessary to facilitate administrative procedures. The pre-application conferences will be held to clarify the requirements and proper procedures for the application for all necessary permits. Scheduling of the conferences will be arranged at a mutually convenient time for both the NJDEPE and applicant. The pre-application phase may consist of a series of meetings. For example, the first meeting will describe the application process. The second meeting is for the applicant to present the facts of the site and to discuss model selections. The third meeting will review the computer model data packet. The applicant is to provide a survey of existing conditions of the site and to prepare a map indicating the location of the proposed golf course and receiving waterbodies. Additional meetings may be needed as information is provided to the Department.

II. Application Packet Preparation and Submittal

In addition to the standard requirements under the appropriate rules and based on the pre-application conference, the applicant will obtain all of the required information and/or perform required studies necessary to complete the permit application. Information required to

Figure II.1

Administrative Process



complete the application includes, but not limited to:

A. Survey and site plan, Environmental Impact Statement (CH. 3);
B. Modelling activities and water quality assessment report (CH. 4);
C. Best Management Plan (BMP) and pollution prevention plan (CH. 5);
D. Monitoring plan (CH. 6); and
E. Pesticides and fertilizers action plan (CH. 7).

Table II.1 shows a partial summary list of information required for the application package.

Table II.1 PARTIAL SUMMARY OF INFORMATION NEEDED FOR REVIEW

I. General Site Specific Information A. USGS Maps (1:24000) of study area and GIS maps, if available. B. Topographic maps (1:2000) showing existing and proposed drainage areas and land uses including slopes, pervious and/or impervious coverages, etc. C. Proposed golf course layout and information including grasses to be used, distribution of greens, tees, fairway, ponds, waterway system, etc. D. Information and/or data (hydrogeometric, hydrological, formation, and other concerns) of waterways potentially impacted by proposed golf course. E. Soil types and other soil data including hydrological soil type, permeability, etc., to be outlined on the site location map. F. Groundwater information including location of groundwater table, depth and thickness of aquifer, flow direction, etc. G. Identification of classification of potentially impacted waterways.
II. Golf course modelling and receiving water quality modelling A. Models used for golf course and receiving water impact assessment. B. Complete report of impact analysis on study area and receiving waterways including coefficients, parameters, constants and their justifications, reference, and rationale for selection, etc.
III. Pesticides and Nutrient (Fertilizer) A. The pesticides/herbicides to be applied and their application frequencies & rates. B. Kinetics and coefficients of fates of pesticides and herbicides C. Dosages and application frequencies & rates for nutrients and/or fertilizers to be applied to golf course. D. The concentrations of pesticides and nutrients in soils and ponds within an existing golf course.
IV. BMPs/Pollution Prevention Analysis.

Chapter 3. Survey Plan, Site Plan and Environmental Impact Statement

I. Survey Plan and Report

The applicant will provide the NJDEPE with a survey of the site to determine the existing environmental conditions. The applicant will also submit to the NJDEPE at the pre-application conference a survey report with accompanying plans which include, but not limited to, the following information at the proposed golf course site:

- Name of watershed(s) and subwatershed(s);
- Location of streams, ponds, or other waterbodies and their classification and use designation;
- Location and classification of wetlands with information on identification of vegetation type, and soil classification;
- Calculated 100-year floodplain;
- Topography with slopes differentiated as less than 10%, 11-19%, and larger than 20%;
- Existing land cover (e.g., forest, meadow, etc.);
- Location of significant plant and/or animal habitats, if available, including: documentation of species, date of last known sighting, status, and source of documentation; and
- Map of golf course outlined on appropriate Soil Conservation Survey map showing various soil types at the site.

II. Site plan

An objective of the site plan is to design the golf course so that there are no encroachments on the areas restricted from development and to minimize the impact of the overall site development on the natural resources of the area.

A. Regulated Environmentally Sensitive Areas

The applicant will identify on the site plan those areas such as wetlands which are regulated by the Land Use Regulation Program (LURP). LURP will provide advice and guidance for such site specific issues. The applicant is to also identify on the site plan the surface and ground water classifications. For questions regarding the State's classification of surface water and ground water, the applicant is to consult with the Department's Office of Land and Water Planning.

B. Design standards

After the applicant has identified those areas to be restricted from development, the site plan should also delineate the proposed layout of the golf course. This plan should include, but not limited to, the following:

1. Tees, greens, fairways, and practice range;
2. Buildings (e.g. clubhouse, maintenance facilities, residential area, etc.);
3. Roads and parking lots;
4. Conceptual design for management of stormwater runoff and water quality including locations, methods and documentation that these locations and methods are practical;
5. Location of irrigation wells and/or ponds;
6. Classification of waters;
7. Possible endangered and threatened species;
8. Detention and retention basins; and
9. Irrigation and surface water drainage.

Storage ponds and/or irrigation wells constructed for irrigation purposes or for storage of recycled runoff water, will not be located in an area where they will impact the potable water supplies or any other sensitive areas.

Where irrigation wells are proposed, a stream depletion analysis may be required. In the event that a depletion analysis is required, an assessment of the impacts of stream baseflow reductions on instream habitats will also be required. In construction of ponds requiring stream depletion analysis, the following impacts should be addressed: (i) changes in organic material transport; (ii) invertebrate drift; (iii) fish passage; and (iv) loss of wetland functions.

C. Stormwater Management and Water Quality Management
The applicant will include in the site plan, plans for management of stormwater runoff. Emphasis should be placed on the use of a combination of methods, such as infiltration trenches, grassed swales, shallow marshes, vegetated filter strips and forest buffers to provide water quality management. Appendix C presents several control measures for controlling stormwater and infiltrate.

III. Environmental Impact Statement

The applicant is to also submit an Environmental Impact Statement relating to the project for which he/she is requesting a permit. For the specific requirements of the Environmental Impact Statement the applicant is to contact LURP.

Chapter 4. Technical Procedures for Modelling

In order to assess the extent of potential contamination of nutrient and pesticides in surface and ground water systems which receive surface runoff and subsurface inflow from the proposed golf course, the applicant may be required to develop a mathematical model to assess the fate and transport of pesticides and nutrients in these hydrologic systems.

I. General

If modelling work is required, the applicant should follow the Department's technical guidelines and directions to perform all the modelling activities. The applicant, with the Department's consent, should select the appropriate model and submit the work plan to the Department for review. The work plan should include a Quality Assurance/Quality Control (QA/QC) plan, model and users manual, and proposed sampling program. The final report should include the model application, input files, results, findings and conclusions; and should be submitted as a complete package to the NJDEPE for review. The important pollutants for modelling should consist of present and proposed pesticides and fertilizers which are to be used at the site. Figure IV.1 is the flow chart for performing the modelling activities for the golf course impact analysis.

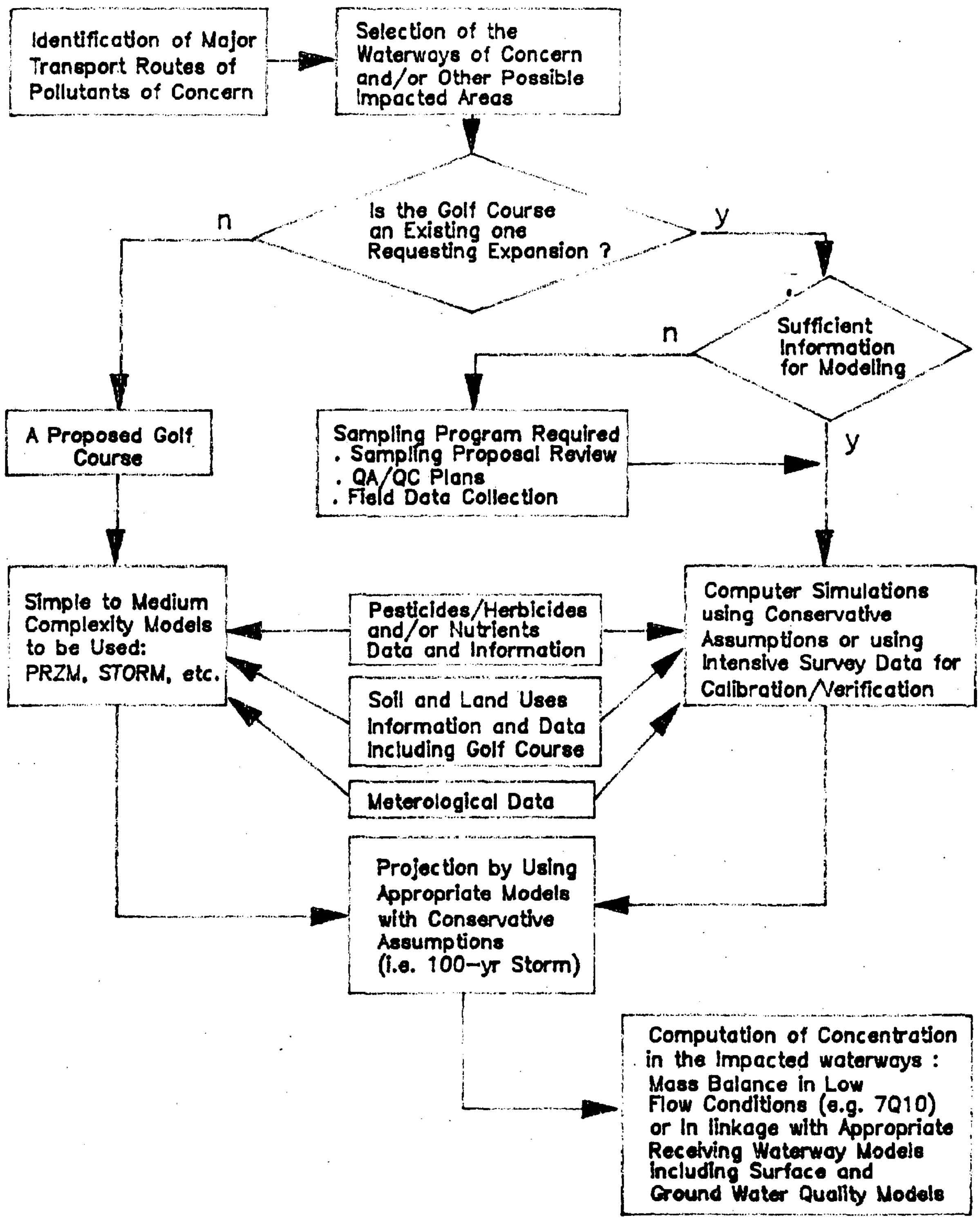
II. Technical Procedures

The procedures for modelling includes:

A. Identification of Waterbodies of Interest,
B. Selection of Appropriate Models,
C. Sampling Requirements, and
D. Model Simulation and Prediction

Figure IV.1

Modeling Activities for Golf Course Impact Analyses



A. Identification of Waterbodies of Interest

Based on the proposed golf course plan, the drainage area, which may be impacted by operation of the golf course, should be delineated. The waterbodies, with their State assigned classifications, including surface waters and ground waters, should be clearly indicated in the study plan. The study plan should include, but not limited to, the QA/QC plan, topographic map and ground water flow maps. These should be submitted to the NJDEPE for review.

B. Selection of Appropriate Models

Once the waterbodies are identified, appropriate models need to be selected for assessment of short-term and long-term impact to surface and ground waters caused by golf course operations. In general, the proposed models should include a watershed runoff model, a receiving water model and a ground water model. The complexity of the required models will be decided on a case-by-case basis.

Many different models have been developed to simulate the fate of pesticides and nutrients transported from surface runoff and subsurface inflow to the receiving water system. The value of these models is their capability to predict impacts resulting from pesticide usage. Shoemaker et al. (1990) have listed several models with their capabilities for simulation of nutrients and pesticides (see Table IV.1). Watershed models such as SWRRBWQ (Simulator for Water Resources in Rural Basins - Water Quality; Arnold et al., 1991) and CREAM (Chemicals, Runoff, and Erosion from Agricultural Management Systems; Knisel, 1980) are good candidate models for the simulation of fate and migration of pesticides and fertilizers. Any model, as long as it is suitable for nutrient and pesticide simulations, can be provided to the Department for consideration.

Table IV.1 Simulation Capabilities of Several Pesticide Models

Model	Timestep	Runoff	Erosion	Vadose Transport	GW Transport
CMIS	Daily	no	no	yes	no
GLEAMS	Daily	yes	yes	Partial	no
LEACHMP	Varies	no	no	yes	no
MOUSE	daily	yes	yes	yes	yes
PESTAN	n/a	no	no	yes	no
PRZM	Daily	yes	yes	yes	yes
SESOIL	Seasonal	yes	yes	yes	no
SWRRBWQ	Daily/ Seasonal	yes	yes	no	no

Source: Modified from Shoemaker et al., 1990.

C. Sampling Requirements

1. For the proposed expansion of an existing golf course, one of the following two sampling plans should be considered:

   a. Baseline data: Representative samples of soil and water should be taken during a dry-weather period in the study area. These data will be used as a baseline to represent the initial background conditions of water quality for the model input necessary to predict the water quality impact due to the future expansion. In general, the sampling sites should include: low level golf course areas (soil), subsurface inflow (ground water) and receiving waterbodies (water). As a conservative approach, the model constants, unit areal pollutant loading and hydrologic conditions applied, should be relatively conservative.

   b. Intensive sampling surveys: Three sets of data should be collected including one baseline sampling and two wet-weather samplings. The first set of data should be collected during a dry-weather period to represent baseline data, and two other sets of data should be collected during wet-weather periods for model calibration and verification. The wet-weather sampling should be conducted under different storm event conditions (i.e. frequency of occurrance, duration, etc.).

      The sampling sites should be selected based on the topography of the existing golf course and the characteristics of the drainage area.

2. For a proposed new golf course, the sampling and modelling procedures will be similar to the

requirements of item 1.a, the exception of the sampling sites. The sites should be selected based on the current natural condition of the proposed golf course area. Any input values, which were derived from the literature, used for model projections should be selected, based on the most conservative assumptions.

D. Model Simulation and Prediction

Information required for model simulations include: 1) pollutants of interest; 2) soil type and texture, land uses, and drainage area; 3) meteorological data; 4) waterbodies of concern; and, 5) the baseline data for pesticides and fertilizers in the soil and ponds within the golf course and receiving waterbodies including surface and ground waters. Typical input information required, based on functions of model simulation, are summarized in Table II.1.

Appendix A presents an example of modelling simulation for a proposed golf course.

Chapter 5. BEST MANAGEMENT PRACTICES AND POLLUTION PREVENTION

A best management practices plan (BMP) and pollution prevention plan for the golf course will be developed by the applicant and submitted to the Department to minimize the impacts caused by the construction and operation of the golf course.

High quality turf is not necessarily the result of increased fertilizer and pesticide usage. An outstanding golf course is the result of excellent design, construction, utilization of best management practices (BMPs), selection of the best turfgrass varieties available at the time of establishment and proper management of the facilities. The golf course applicant will develop a BMP program in coordination with NJDEPE. BMPs are practices employed to reduce chemical and fertilizer dependence, water usage and all other impacts to receiving waterbodies through proper construction and operation of the golf course. The superintendent of the golf course will be required to implement and further refine the BMP program over time. As such, record keeping, reporting, monitoring and modifications are necessary to ensure that current practices are used. The application of BMPs requires the knowledge of many disciplines such as: entomology, plant pathology, weed science, nematology, wildlife biology, agronomy, soil science, meteorology, plant genetics, hydrology and economics.

It should be kept in mind that the differences between the physiographic regions of the state including soil, topography, hydrology and climate will impact construction and management practices to be employed, as well as the appropriateness of siting a golf course.

I. Possible Pollution Source Categories

A. Golf Course Construction

Soils exposed, disturbed and stockpiled from golf course construction activities may result in significant losses of water, sediment and nutrients. Sediment loadings from construction sites may be as much as 100 times greater per acre than those from agricultural lands and perhaps 2000 times greater than those from undisturbed forest land. Suspended solids represent not only an important pollutant in themselves, but are also a principal transport vehicle for other pollutants such as pesticides and metals. Golf course construction often involves the disturbance of an unusually large amount of land. Unless runoff is properly managed during construction, increased erosion and sedimentation, increased turbidity, decreased aquatic productivity and reduced water quality on site as well as downstream will result.

Factors affecting runoff rates and volumes include:

- Precipitation duration, intensity and spatial extent;
- Size, shape, orientation, topography and geology of the golf course watershed;
- A soil's physical and chemical properties, infiltration capacity and antecedent soil moisture conditions;
- Type and extent of grass cover (sod vs. seed);
- Cultural practices (Watson, 1985; Welterlen, 1989);
- The duration and extent of soil disturbance; and
- The use of mitigating soil conservation practices (Balogh and Walker, 1992).

When developing a site plan, these factors should be thoroughly investigated and BMPs chosen accordingly. Site planning should include not only long term Nonpoint Source (NPS) management, but should also incorporate temporary BMPs (including timing and methods of construction) designed to control stormwater runoff during construction.

B. Turf and Landscape Maintenance

Fertilizers and pesticides are used extensively in the maintenance of turf and ornamental plants on golf courses.

High quality turfgrass is necessary in order to meet the demands of the public and to compete in the golf course industry. As a result, the level of landscape management is steadily increasing in the United States. Although a well maintained plant community can be an environmental as well as a recreational asset, water quality can be severely degraded if proper maintenance practices are not employed.

Excessive and improper application are the major problems associated with fertilizers and pesticides. These common misuses often lead to ground and surface water contamination. Some water quality impacts associated with these pollutants include the following:

1. Rapid short term changes in water quality from stormwater runoff;
2. Longer term water quality impacts on biological communities and public health resulting from pollutants entering surface waters;
3. Impacts on the quality of ground water in aquifers utilized as sources of drinking water.

Nitrogen and phosphorus in fertilizers are linked to eutrophication and subsequent deterioration of surface water quality, as well as ground water contamination. The movement of nitrates into ground water may cause a public health hazard because high nitrate concentrations can cause infant methemoglobinemia (Blue Baby Syndrome). Numerous acute and chronic effects are similarly associated with pesticide exposure to humans and other organisms. These toxic substances can enter an organism through inhalation, ingestion or skin contact. Pesticides have caused decreases in aquatic populations either directly through damage to the food chain by decreasing reproductive success, or by indirectly reducing oxygen levels in the water by reducing the populations of higher plants and phytoplankton.

An additional concern in the intensive management of turfgrasses is the excessive use of water. Traditionally, many turfgrass managers have used water on golf courses as if inexhaustible in supply (Youngner 1970; Shearman 1985). In recent years water policy in this country has been driven by the realization that water is a limited commodity. The depletion of water supplies for drinking, recreation and other human uses has resulted in increased awareness regarding water consumption.

C. Golf Course Facilities

The construction of clubhouses, pro shops, food and beverage facilities and parking lots as well as maintenance and storage structures causes water quality impacts similar to traditional commercial development. Runoff from these areas contributes sediment, heavy metals, fecal bacteria, organic and inorganic debris, household chemicals, and oil and grease from motor vehicles to surface and ground water. Since most of the facilities mentioned above require extensive impervious surfaces, stormwater runoff volumes are much heavier than pre-development conditions. The impacts of higher pollutant export are felt not only on adjacent streams, but also on downstream receiving waters such as lakes, rivers and estuaries. Improper design, poor construction and lack of maintenance of golf course facilities will magnify these impacts.

II. Best Management Practices

A. Identify Site Constraints

Identify and inventory natural resources with an emphasis on critical and unique habitats:

- Vegetative cover
- Wildlife habitat

- Surface water classification
- Ground water resources
- Soil types
- Drainage patterns
- Steep slopes
- Wetlands
- Threatened and endangered species and habitat

Working over a topographic map of the site as a base, delineate the boundary of each area by carefully determining the limit which should not be crossed by construction activity without causing adverse impact. For example, when plotting a natural drainageway, map its flow line, but also be sure to include that area of the adjoining side slopes which, if disturbed, would cause a loss of integrity in its hydrologic function (i.e. top of bank to toe of slope in a steep slope area). For critical areas, a BMP program should be developed and implemented such that no impairment or deterioration will occur.

B. Alternative Course Layout and Design

- Reduce area of tees, greens and fairways.
- Preserve roughs in their natural state.
- Develop traffic patterns which minimize surface runoff, soil compaction, pests, nutrient deficiencies and water usage.
- Maintain natural drainage patterns and maintain or increase quality of water on site and/or leaving the site.
- Avoid wetland and stream corrider disturbances. Fairways should be sited to reduce the number of crossings with streams, wetlands, forests, etc. Greens and tees should be located in areas where the maximum high water table or bedrock is greater than four feet below the surface. Field determination of high

bedrock and/or ground water should be conducted with respect to the final setting of those locations. Underdrain systems for greens and tees must also maintain four feet of soil separation between the subsurface leaching system and high bedrock and/or ground water.

- Maintain and establish buffer strips along the perimeter of wetlands. Wooded buffers which shade streams are preferred.
- Avoid loamy sand soils to the greatest extent possible.
- Designate conservation easements.
- Designate wildlife sanctuaries.
- Locate buildings and other impervious surfaces in areas which will minimize land disturbance.
- Minimize impervious surfaces.
- Where impervious surfaces are necessary, reduce the amount of runoff generated.
- Carefully locate and design any stormwater facilities that may be necessary.
- Locate and design pesticide and fertilizer storage facilities in such a way that spills will not affect water quality.

C. Construction Practices

1. Implement soil erosion and sediment control practices in compliance with the "Standards For Soil Erosion and Sediment Control in New Jersey" developed by the State Soil Conservation Committee and enforced by the local Soil Conservation Districts. Immediate coverage of bare soil surfaces with seed or sod in conjunction with other soil stabilization measures should be emphasized.

2. Implement special soil erosion and sediment control practices which address the unique pollution problems associated with golf course construction.

a. Extensive phasing of construction activities to reduce the impacts associated with large areas of disturbance.

b. Increased buffers to wetlands and other environmentally sensitive areas for soil stabilization and attenuation of the pollutants potentially generated by golf course construction in large amounts.

c. Avoid irrigation rates or duration which may cause runoff of water, resulting from irrigation of turfgrass at rates greater than soil infiltration rates and soil storage capacity (Balogh and Walker, 1992).

d. Where preferential flow paths are evident, wet detention basins should be considered provided conditions are suitable.

e. Delivery reduction devices should be properly designed, sited, constructed and maintained. Regional considerations should be accounted for the design of stormwater facilities (e.g. downstream effects of detention basins).

D. Source Controls

1. Choose the proper turfgrass species for greens, tees and roughs (if necessary):

   a. Native species should be used whenever possible. When it is not feasible to utilize native turfgrass species, choose a species or cultivar which is suited to the climate as well as physical and chemical characteristics of the site. When planting is necessary in rough areas, natives should be used exclusively.

   b. Select species and cultivars of turfgrass capable of efficient water use and drought resistance. Research has been completed and data are available on rates of turfgrass evapotranspiration as well as drought resistance.

c. Select species and cultivars of turfgrass that minimize nitrogen loss through volatilization, leaching and surface runoff. Data are also available concerning nitrogen loss characteristics of various turfgrass species.
d. Select species and cultivars of turfgrass which are resistant to pests and diseases common to your geographic location.
e. Select turfgrass species or mixtures which will compete favorably with weed species based on existing and proposed site conditions. Seed mixtures should be weed free.

2. Use proper fertilizer management practices:
   a. Use organic slow release fertilizers to the greatest extent possible and avoid the use of soluble fertilizer. The type of nitrogen fertilizer applied significantly influences the availability of nitrogen to grass uptake and to runoff or infiltration. The more soluble the fertilizer, the more easily it can be transported away from the application site, either through runoff or by infiltration. Examples of water soluble fertilizers include ammonium nitrate, potassium nitrate, urea and calcium nitrate. These compounds are more readily available to the turf plants and therefore are actively used. However, large applications of these types of fertilizers followed by heavy rains or irrigation may exceed the capability of turf grasses to assimilate the nutrients and therefore result in leaching to ground water or being carried in runoff water. Some examples of slow release fertilizers are urea formaldehyde, isobutylidene diurea (IBDU), sulfur coated urea (ISU) and plastic coated urea. Several

recent studies (Cohen et al. 1990; Horsley and Moser, 1990) have shown that the use of slow release fertilizers reduces nitrogen loading to the ground water. See Appendix B for additional information on the fate of nitrogenous fertilizers.

b. Test soils to determine nutrient requirements. Nitrogen should be applied to turf in amounts no greater than the amount required for plant uptake.
c. During the turf establishment phase of construction, usually a six to nine month period, use sod filter strips of at least six meters in width around seeded slopes (Mason, 1990).
d. Avoid the use of fertilizers in roughs.
e. In areas of a high water table, in order to prevent ground water pollution, an underground drainage system can be employed and leachate can be recycled to areas of greater depth to water table, detained or treated prior to release.
f. Irrigation rates should approximate evapotranspiration rates. Overwatering significantly increases nitrogen losses.
g. Avoid turf establishment on sandy soils to the greatest extent possible. The greatest potential for contamination of ground water comes from soils with high infiltration rates.
h. Maintain buffers to wetlands.
i. Whenever possible, incorporate fertilizers below the soil surface.
j. Increase time between fertilization and rainfall events to the greatest extent possible.
k. Light irrigation after application is recommended to incorporate fertilizers into the soil.
l. Fertilize during periods of maximum plant uptake. Fall and winter fertilization should be avoided.
m. Proper handling of fertilizers during equipment loading and mixing is critical. Avoid spills at all

costs and immediately clean up any spills which do occur.

n. Fertilize when the soil is moist, as grass will not take in nutrients during dry periods.
o. Soil preparation should occur prior to seeding.
p. Establish turf during fall, this way when growing season begins in Spring, turf has a greater chance of out competing weeds.

3. Use proper pesticide management practices:
The concept of a Integrated Pest Management (IPM) program is to avoid wherever & whenever possible, the use of chemical pesticides through the substitution of other control measures. The following is a list of some of these control measures.
   a. IPM techniques should be utilized at all times.
   b. The first steps in IPM are: selecting plants which are indigenous to the area, pest resistant, establishing proper cultural practices, sound fertilization techniques, and suitable irrigation methods. Only seed sources known to be weed free should be used to reduce the introduction of weed species during early turf establishment. Cultural controls include activities such as mowing, aeration, dethatching, fertilization and irrigation. Cultural controls are used to manipulate pesticide populations by culturing the crop to decrease the survival of the specific pest and to promote proper turf development. This will promote turf which is resistant to and able to recover from pest damage.
   c. Establish thresholds for unacceptable economic or aesthetic injury based upon a reliable measurement system. The mere presence of a pest organism does not necessarily constitute a pest problem.
   d. Monitor the environment and pest populations on a periodic, consistent basis.

e. Take action that modifies the pest habitat to reduce the carrying capacity of the site, excludes the pest or otherwise makes the site environment incompatible with the needs of the pest. In order to do this, a comprehensive knowledge of the life cycle of the pest is necessary.

- Regulatory Controls - Pests may be kept out of an area through quarantine and inspection.
- Genetic Controls - Modify the genetic makeup of the pest population so that it cannot survive. An example is the introduction of sterile males into a pest population to inhibit reproduction.
- Biological control - Introduce and establish populations of natural enemies of a selected pest. An example is the use of Bacillus Thuringiensis and milky spore to control white grub populations. The objective should be to use biological controls wherever feasible to reduce dependency on chemical pesticides.
- Cultural Control - Making the environment unfavorable for pest reproduction, movement or survival. Examples include maintaining plant vigor, pruning, sanitation and species diversification.

f. If pesticides are absolutely necessary, the following techniques are essential to minimize environmental impacts. (The commonly used pesticides for New Jersey golf courses are listed in Table VII.1.)

- Always read the label.
- Select a pesticide that:
    - is legal,
    - is labeled for the plant, site of application and the pest,

- has minimal environmental impacts (analyze solubility, toxicity, mobility, adsorption capabilities and persistence),
- is effective given the site and climate conditions, and

▶ Mix pesticides properly:

- take any special precautions specified on the label,
- never mix more pesticide than is needed
- when adding water to a sprayer, partially fill it, add the pesticide, then continue to fill the tank until it is full,
- the water source should be equipped with an anti-backflow device,
- never mix pesticides near a well, and
- avoid spills at all costs, but if they do occur, clean them up immediately.

▶ Apply pesticides properly:

pesticides should only be applied by properly trained and certified personnel,

- reduce the frequency of application to the greatest extent practical,
- observe weather conditions at the time of application; if rain or high winds are forecast, postpone the application,
- do not allow spray to drift into open water, wetlands or storm drains,
- consider topography; application at a topographic high may impact low areas after a rain, and
- calibrate equipment properly; calibration requires an understanding of the equipment and how it works.

▶ Clean up, store and dispose of pesticides properly:

- clean equipment after use to maintain it in good working order and to remove any residues which would become a part of the next application,
- check for leaks after each use,

- store indoors in structurally sound containers, preferably in a secure, locked and prominently marked enclosure,
- when transporting pesticides, all containers should be secured,
- disposal of unused pesticide material is best handled by using all of the material during applications, giving the material to someone who can use it, or returning the unused portion to the manufacturer directly,
- if these options are not available, pesticides that are either acutely hazardous or hazardous wastes must be disposed of as such, and
- containers must be empty, free from any pesticide residue, triple rinsed, crushed or punctured before being disposed of in a landfill designated for this use.

▶ All pesticide use shall conform with New Jersey's Pesticide Control Regulations (N.J.A.C.- 7:30 Subchapters 1 to 10).

g. Evaluate the results of habitat modification and pesticide treatments.

h. Keep written records of objectives, methods, data collected, actions taken and results.

4. Use proper cultural practices:

a. The mowing height should be the optimum for the species of grass, but in general, the higher the blades are set, the healthier the turf will be.

b. Increases in growth rate from fertilization and other practices should result in an increase in mowing frequency. However, this practice should be balanced with the damage to turfgrass leaf tips resulting from increased mowing frequency. Mowing frequency should increase to match the increased growth. If this doesn't occur, the turf may begin to thin out, leaving it vulnerable to weed infestations. Recent investigations have also suggested that the removal of grass clippings will result in a lowering of the overall risk from residual pesticides.

c. Lawnmower blades should be kept as sharp as possible at all times.

d. A moderate thatch layer is useful in preventing pesticides and fertilizers from leaching into the ground water. The buildup of excessive amounts of thatch creates breeding sites for numerous insects and fungal diseases. Thatch is the layer of living and dead plant material that accumulates between the green vegetation and the soil. A proper balance is necessary to attain a moderate thatch buildup.

e. Irrigation should be based on need, not the calendar. Tensiometers, pan evaporation or other proven quantitative methods should be used to determine need.

f. Irrigation rates should approximate evapotranspiration rates.

g. Irrigation practices should not result in a reduction of stream base flow.

h. Properly design and maintain irrigation systems.

i. Utilize proven soil manipulation techniques such as wetting agents and antitranspirants, if necessary.

j. Irrigate during evening hours.

5. Best management practices should be coordinated to insure compatibility on site and in the watershed.

6. Monitor all results such as disease incidence, pest occurance, health of turn, etc. and keep written records of all of the best management practices employed.

7. In conjunction with BMPs discussed in this manual, for controlling stormwater runoff the applicant shall design the management plan in accordance with current program standards. These standards can be obtained during the

pre-application meeting. In addition, for controlling stormwater runoff from golf courses and associated facilities, the "Stormwater and Nonpoint Source Pollution Control Best Management Practices Manual" (NJDEPE, 1992, Final Draft in print) may be applied where not in conflict with current regulations. Appendix C presents some pollution control measures for use in golf course construction and operation.

III. Conclusions and Research Needs

The Department believes it is necessary to integrate pollution prevention and control early in the site planning process. The BMPs outlined in this chapter are arranged in the order of an effective pollution control program. BMPs which address water quality and quantity issues through preventative measures are listed first, followed by BMPs for pollution reduction. A properly designed golf course which includes a carefully planned BMP program can minimize the impacts to receiving waterbodies and can even provide certain environmental benefits, such as wildlife habitat.

The practices specified above are not all inclusive. Additional research will need to be done in order for this guidance to be comprehensive and detailed. Much remains to be learned about the impacts of golf courses on the environment. New and innovative techniques are continuously being explored as more information becomes available. Through monitoring the effectiveness of the pollution control methods currently used, BMPs may need to be reexamined and modified.

Chapter 6. Monitoring Plans and Requirements

The applicants and/or their consultants will develop a surface and ground water monitoring plan for the golf course. In order to provide protection of receiving surface waterbodies as well as ground waters it is necessary that monitoring programs be carefully designed and implemented. Three monitoring phases will be reqired: the baseline monitoring, follow-up monitoring, and routine monitoring.

The baseline monitoring phase for surface and ground water will be for one year prior to start of construction. The follow-up monitoring phase will begin as soon as pesticides and fertilizers are first applied and will include a period of three (3) years for surface waters and two (2) years for ground water (see monitoring steps in Table VI.1 for additional monitoring details). If no sign of contamination in the receiving waterbodies is found during the follow-up phase, the routine monitoring phase will be initiated. The routine monitoring will be performed on an annual basis and will be conducted in the season of highest pesticide and fertilizer application.

The surface water monitoring will be conducted under wet-weather conditions which generate surface runoff. If other factors such as sensitive soil types, existences of endangered species, high quality receiving waterways, etc. are of concern in the study area, NJDEPE will require more intensive sampling programs on a case-by-case basis.

The QA/QC plan and sampling stations will be submitted by the applicant for Department approval during the pre-application meetings. All sampling is to be done at a New Jersey State Certified Laboratory.

Table VI.1 Proposed Ground Water Quality Monitoring Program at Cape Cod, Massachusetts

1. Monitoring Wells: Installation of six to 10 monitoring wells are planned for future water quality sampling. Monitoring wells will consist of five well clusters with each well cluster containing two to three small-diameter (2-inch) wells, which terminate at different depths within the aquifer (see Figure 6). Three of the well clusters will be located at the south-southeastern downgradient hydrologic boundary of the golf course as determined by ground water flow directions simulated from pumpage of three irrigation wells (150 gpm/well) under transient conditions. Monitor wells along this boundary will be in a position to monitor all possible sources of contaminants originating from within the golf course. A fourth monitoring well cluster will be located along the western boundary of the property. A fifth well will be located downgradient of the pesticide storage facility. These monitor wells will forewarn of any potential water quality impacts to public supply wells 13, 18, 19, 10, 11 and the two proposed wells at 16-77 and 18-77. Wells will be screened both above and below clay layers where present to enable sampling at discrete depths within the aquifer(s) and to determine vertical contaminant stratification. Anticipated well depths for well clusters are as follows: Screen elevations for deep wells will be set at approximately -20 to -30 feet MSL to detect possible contaminants migrating toward well #13 (nearest public supply well) with densities greater than water. Screen elevations for wells at mid-depth will be set approximately -5 to -15 feet MSL to detect possible soluble contaminants at the same elevation as the screen setting for public supply well #13 (-15 to -25 feet MSL). Shallow wells will be screened in saturated materials above clay lenses or beds where present in the upper aquifer or at the water table surface.

   Well construction will consist of 2-inch-diameter flush-threaded joint PVC. PVC is selected for economic reasons and the "superior performance that can be expected of polymeric materials under acidic conditions" (Barcelona 1983), which is generally the case for Cape Cod ground water (Frimpter and Gay 1979). Screens will be 10 feet in length and number 10 slot size. Finished wells will be backfilled with material from the borehole sealed with bentonite to isolate the various screens and capped with a steel security cover that is anchored to a cement base (see Figure 6).

   Locations of the monitor well clusters are indicated in Figure 7. Monitor wells are located in downgradient flow direction as determined from irrigation pumpage for three wells at 150 gpm under transient conditions. The irrigation wells will also serve as monitor wells.

2. **Lysimeters/Drain Fields:** Six pressure-vacuum lysimeters (constructed of Teflon®) and six drain fields will be installed to obtain water samples from the zone of aeration. The drain will lead to a secured collection barrel so as to provide for composite sampling and avoid vandalism. These devices shown in Figure 8 enable sampling of water leaching through the root zone before it reaches the water table. Both devices are proposed due to the lack of direct experience in the utilization of these systems in zone of aeration sampling on Cape Cod. Lysimeters and drain fields will be placed beneath both greens and fairways. Locations shall be upgradient from monitor well locations so as to provide early warning, which may be used to better tailor the ground water monitoring program. Since the wells lie downgradient of a powerline, which has been maintained by Commonwealth Electric, a preliminary round of testing for those herbicides that have been used is recommended to determine background levels.

3. Aeration Zone Sampling/Analysis: Sampling water in the aeration zone directly beneath areas of pesticide application before it reaches the water table will provide a "worst case" assessment of the potential for ground water contamination at the proposed golf course. The results of these analyses will allow for a better planned and coordinated ground water sampling program.

   Using hand pumps, vacuum will be produced on the lysimeters and water samples will be obtained quarterly (four times a year). Quarterly sampling of drain fields will also be undertaken. Samples will be composited (two locations per sample) and analyzed for all pesticides (fungicides, insecticides, and herbicides), nitrate, Kjeldahl, and ammonia-nitrogen. Water samples will be iced and shipped to the analytical laboratory within 24 hours. Chain of custody forms will be utilized to document sampling, shipping, and analytical times.

4. **Resampling/Analysis:** If any pesticides are detected in any concentrations (including trace levels), resampling and analysis will be required for confirmation.

5. **Ground Water Sampling/Analysis:** During the first two years of operation, monitor wells and irrigation wells will be analyzed for target chemicals quarterly (four times per year). Target chemicals are to include all pesticides (fungicides, insecticides, and herbicides) used on the golf course, any known metabolites, nitrate, Kjeldahl, and ammonia-nitrogen. Sampling will be accomplished using dedicated Teflon bailers following the evacuation of three to four well volumes. Water samples will be iced and shipped to the analytical laboratory within 24 hours. Chain of custody forms will be used to document sampling, shipping, and analytical times.

6. **Resampling/Analysis:** If any pesticides are detected in any concentrations (including trace levels), resampling and analysis will be required on those wells on a weekly basis until two consecutive sampling rounds show no detection of those chemicals.

7. **Sampling/Analytical Frequency Re-evaluation:** After a period of two years, water quality data will be compiled and reviewed. For those pesticides that have not been detected in either aeration zone samples or ground water samples, the analytical frequency will be reduced to annual (once per year) thereafter. Those pesticides that have been detected (and confirmed) will continue to be analyzed quarterly (four times per year). Regardless of these results, nitrogen components will continue to be monitored quarterly.

8. **Pesticide Restriction:** During the resampling and testing, the use of the parent pesticide will be discontinued. If the detection of chemicals persists for a period of two consecutive samplings, the use of the parent pesticide (fungicide, insecticide, and/or herbicide) will be eliminated permanently. New pesticides proposed for use on the golf course must be approved by the Yarmouth Water Quality Committee. This approval will be based upon the submittal of appropriate technical information from EPA or other recognized environmental research institutions. The Water Quality Committee should also reserve the right to discontinue the use of certain pesticides as new information becomes available.

9. **Justification for Remedial Action:** If pesticides are measured in concentrations of 100 parts per billion (ppb) or greater (either individual compounds or collectively) or as defined by EPA drinking water standards as they become available, a hydrogeologic investigation will be undertaken to delineate the area of ground water contamination and specific sources. Remedial actions including mitigation and cleanup will be formulated and implemented.

Table VI.1 Proposed Ground Water Quality Monitoring Program at Cape Cod, Massachusetts (continued)

10. **Resampling for Total Nitrogen:** If total nitrogen levels (Kjeldahl plus nitrate-nitrogen) reach 5 mg/L total nitrogen, or greater, resampling and analysis will be required on a weekly basis until two consecutive rounds are below 5 mg/L.
11. **Fertilizer Restriction:** If total nitrogen levels above 5 mg/L are found, the application of fertilizer will be decreased proportionate to the percentage of excess nitrogen concentrations. For example, a concentration of 6.0 mg/L total nitrogen measured in a monitoring well would represent a level of 20 percent above the planning guideline of 5.0 mg/L. Corrective action would require a reduction of 20 percent in fertilizer applied to the turf area upgradient from the well.
12. **Justification for Remedial Action:** If total nitrogen is measured in concentrations of 10 parts per million (ppm) or greater, a hydrogeologic investigation will be undertaken to delineate the area of ground water contamination and specific sources. Remedial measures, including mitigation and cleanup, will be formulated and implemented.
13. **Water-Level Monitoring:** Observation wells OW-15, OW-2, OW-3, OW-4, and OW-5 shall be monitored for water table fluctuations. The timing and frequency of these measurements will coincide with the current water level monitoring program conducted by the Yarmouth Water Department (which is twice/month at present) for the first year of operation. At the end of the first year, the results of this monitoring effort will be reviewed by the Yarmouth Water Quality Committee.
14. ***Pumping Restriction:*** If water level observations demonstrate a more pronounced impact on the water table than that which was predicted by the computer model, the Yarmouth Water Department (in conjunction with the Yarmouth Water Quality Committee) can place restrictions on the pumping of the irrigation wells. Water usage restrictions may also be ordered by the Yarmouth Water Department during drought conditions. Specifically, the following restrictions may occur: (a) when a "voluntary restriction" order is issued to the public, the irrigation pumping will be reduced by the same proportion that occurs with the Yarmouth Water Department pumping, and (b) when a "water ban" is issued to the public, a 100 percent reduction in irrigation pumping will be implemented. Under this scenario, irrigation will be derived from the golf course storage pond.

To ensure proper implementation and enforcement of the proposed monitoring program, a cooperative agreement should be developed and executed between the Golf Course Committee and the Yarmouth Water Quality Committee. The agreement should include (1) the operative provisions of the monitoring program as described previously, (2) a requirement that monitoring results be submitted upon receipt, and an annual report assessing the water quality data to the Yarmouth Water Quality Committee and the Yarmouth Water Department, and (3) provision for a contingency fund or environmental liability insurance worth at least $50,000 for hydrogeologic investigations/remedial actions in the event that unacceptable ground water contamination occur. A schedule of the water-quality monitoring program tasks and the responsible organizations is shown on Table 3.

I. Ground Water Monitoring Program

Two concerns regarding potential ground water impacts caused by operation of golf course to the ground water are:
1) hydrologic impacts upon downgradient wells and 2) water quality impacts from fertilizers and pesticides. A case study on Cape Cod, Massachusetts, for a ground water monitoring program at a golf course (S. W. Horsley and J. A. Moser, 1990) is recommended for adoption as a basis for ground water monitoring program at New Jersey's golf courses with modifications. The proposed ground water quality monitoring program of Cape Cod is presented in Table VI.1. In summary, the monitoring program includes the following:

A. Monitoring wells

Monitoring wells are to be located along the boundary of the golf course so as to monitor all possible sources of contaminants originating from within the golf course. Wells are also to be located upgradient and downgradient of the site. Site locations of these monitoring wells will be approved by the Department at the pre-application or other appropriate meetings.

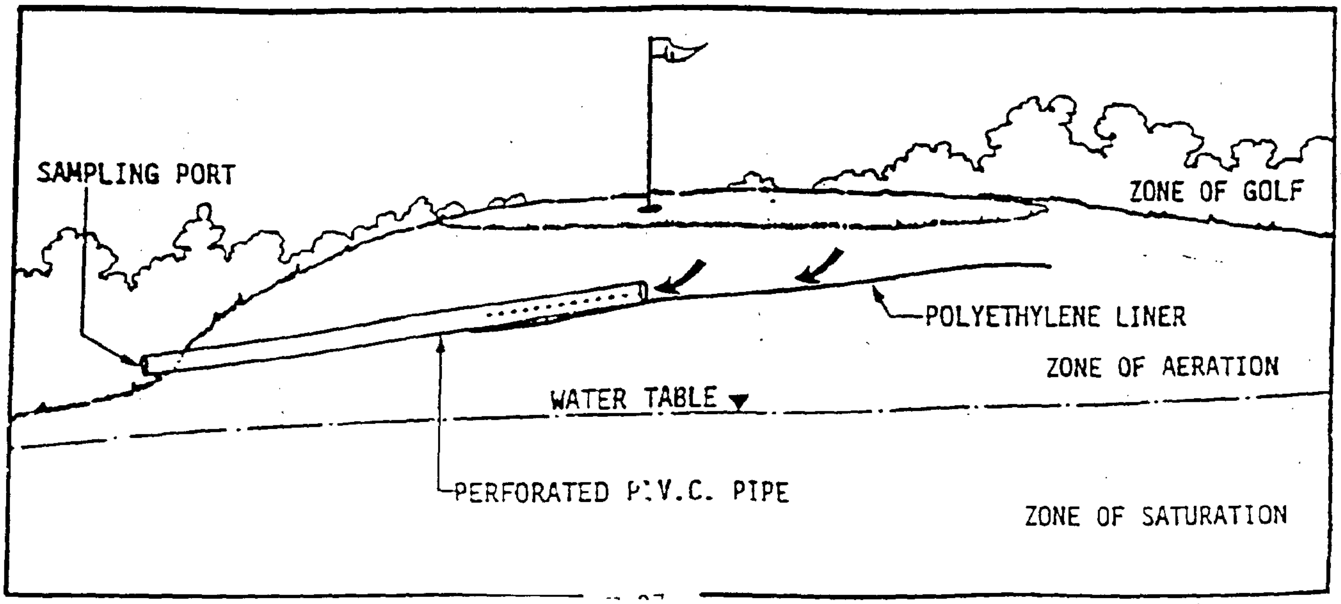
B. Lysimeter/Drain fields

Pressure-vacuum lysimeters and drain fields are recommended be installed beneath greens and fairways to obtain water samples from the zone of aeration. An example of these devices is shown in Figure VI.1. These devices will enable sampling of water leaching through the root zone before it reaches the water table.

C. Sampling/analysis

The applicant is to contact the Office of Land and Water Planning to identify groundwater standards for the parameters listed below. The applicant is to sample each monitoring well for target chemicals quarterly (four times per year) during baseline and follow-up phases and once per

Figure VI.1 Drain Field Design for Subsurface Water Sampling



year during the routine monitoring phase and/or as specified by the Department based on application rates of pesticides and fertilizers. Target chemicals for sampling are to include:

1. all pesticides (fungicides, insecticides, and herbicides) used on the golf course,
2. any known metabolites,
3. nitrate, Kjeldahl nitrogen, and ammonia-nitrogen and other fertilizer related chemicals used on the golf course.

Additional monitoring rates and sites may be necessary when the golf course is located next to or near wells used as a source of potable water.

D. Ground water quantity monitoring
   1. Ground water level monitoring - To provide an additional degree of protection to adjacent well supplies, water quantity wells should be identified and maximum drawdown levels established for each. The applicant will provide the following information:
      a. natural water table fluctuations prior to golf course development and initiation of the irrigation process, and
      b. ground water elevations for pre-determined monitoring wells.

   2. Pumping restriction - If water level observations demonstrate a more pronounced impact on the water table than that which was predicted by desktop computation or the computer model, NJDEPE can place restrictions on the pumping of the irrigation wells. Water usage restrictions may also be ordered by the NJDEPE. To determine if a permit is necessary for the irrigation

pumping system the applicant is to contact the Bureau of Water Allocation.

E. Reporting Requirements

After the follow-up monitoring period, the applicant must compile and submit to the Department the ground water quality data. For those pesticides which have not been detected in either aeration zone samples or ground water samples, the sampling frequency will be reduced to annual testing. If the concentrations of pesticides or fertilizers related pollutants are found to be higher than the allowable limits, the Department should be notified immediately and the application of pesticides and fertilizers should be terminated for further investigation of the causes.

II. Surface Water Monitoring Program

A. Chemical Monitoring

Monitoring sites will be determined at the pre-application meeting. The surface water parameters are to be monitored on a quarterly basis (March, June, September, and December) during baseline and follow-up phases and on an annual basis during the routine monitoring phase.

Storm water samples collected during the follow-up phase should coordinate with golf course operations. If a storm event occurs within a week after the application of fertilizer and/or pesticide, monitoring should be conducted.

The parameters required to be monitored are:

pH,
DO,
Alkalinity,
Total suspended solid,
Total phosphorus,
Total Kjeldahl nitrogen,

Ammonia nitrogen,
Nitrite-nitrate nitrogen,
Turbidity,
Pesticides (i.e. Fungicides, Insecticides, and Herbicides, etc.), and
Fertilizer components (if applicable)

Pesticides and fertilizers to be monitored will be determined by NJDEPE in cooperation with the golf course superintendent, and/or the developer's environmental consultants. For surface water quality standards, the applicant can contact the Office of Land and Water Planning.

B. Benthic Macroinvertebrate Monitoring

1. The assessment will include the following:

   Taxonomic composition (at least to genus),
   Abundance (mean density),
   Taxa richness,
   Diversity index (e.g. Shannon-Weaver),
   Biotic index,
   Functional group analysis.

2. Sampling will be conducted in the fall (e.g. late October/early November) and in the spring (e.g. late March/early April) at each of the sampling stations during baseline and follow-up phases.

   Stream morphology and/or ground water aquifer or other reguired information should be submitted as shown in Table II.1.

C. Reporting Requirements

All test results data will be compiled in a report which will be submitted to NJDEPE at the end of each quarterly monitoring period. All field notes and laboratory records should be available upon request.

Chapter 7. Pesticide and Fertilizer Plans

In order to apply pesticides on lawns or turf at a golf course, the applicator must obtain a New Jersey pesticide applicator license in the appropriate category. The Pesticide Control Program (PCP) of NJDEPE will provide advice and guidance for pesticide related issues. The phone number for PCP is 609-530-4070. For advice on pesticide selection, contact your County Cooperative Extension Office. Note: Pesticide means and includes any substance or mixture of substances labeled, designed, or intended for use in preventing, destroying, repelling or mitigating any pest or for use as a defoliant, desicant, or plant regulator.

Landscape management of a golf course requires the establishment and maintenance of a healthy turfgrass. In order to achieve this, fertilizers and pesticides are often required to control insects, weeds, and turfgrass diseases. Application of pesticides and fertilizers has drawn increasing public concern and more attention and effort is needed to prevent or minimize adverse impacts on the environment and human beings. Some impacts to the environment which could be minimized through the careful selection, management, and application of pesticide and fertilizers include:

A. contamination of potable and non-potable ground waters and surface waters;
B. wildlife kills, particularly fish and bird kills, due to the incorrect application and/or use of pesticides;
C. foodchain accumulation; and
D. adverse human health affects though the application, exposure and/or ingestion of pesticides.

Concerning the above topic, it is important to note that the instuctions on the label of the pesticide container are regulated State and Federal requirements and improper application of the pesticide is a violation of State and Federal regulations.

I. Required information for pesticides and fertilizer action plan

Information on pesticides and fertilizers to be applied to the golf course should be included in the application package. The pesticide and fertilizer action plan shall contain the following information:

A. Name of the golf course;
B. Identification of areas where pesticides are to be applied;
C. Name and mailing address of golf course superintendent who is responsible for completing the application package;
D. Storage, handling , mixing and loading procedures;
E. Target pest, target site, method of application, rate of application, irrigation practices (if any), crop and the percent of foliar ground cover;
F. Site specific data for each of the following:
   1. Top soil horizon depth;
   2. Depth to seasonal high water table;
   3. Soil Conservation Service Soils Hydrologic Group;
   4. Soil test results of percent organic matter;
   5. Any available monitoring data including a list of wells on the site and location of sampling stations in the receiving waterbodies;
   6. Other data which supports a finding that the anticipated site is not a highly vulnerable site. The definition of highly vulnerable site, adopted from the Department of Food and Agriculture, Massachusetts, refers to a site which meets or exceeds the following criteria:

      a. Soil Conservation Service Hydrologic soil Group A soils, whose products of the top soil horizon, in inches, and the soil organic matter, in percent, is less than or equal to fifteen (15); and
      b. The depth to the aquifer is less than 15 feet; and
      c. The depth to the fractured bedrock or seasonal high water table is less than four (4) feet.

G. Post action inspection and monitoring - Following the application, it is necessary to perform investigations and inspections to determine the effectiveness of the specific action. There may be a need to attempt another control method to reduce the pest population below an acceptable level. Complete eradication of the pest will lead to an over use of chemicals and result in ground water contamination.

Golf courses are not to be constructed in areas falling under the category of a highly vulnerable site.
All information submitted in the application must reference the source of the data. The Department reserves the right to request additional information from the applicant at any time throughout the review process.

II. Commonly Used Pesticides in New Jersey

Information regarding major pesticides and their available analytical methods, as provided by PCP (Pesticide Control Program), NJDEPE, is listed in Table VII.1. Table VII.2 presents the environmental fate characteristics of pesticides and Figure VII.1 delineates the pesticide frequency of application on New Jersey golf courses. Appendix D shows NJDEPE laboratory routine capability for pesticide analysis and provides figures demonstrating the potential variability of pesticide use on a representative golf course including fungicide, herbicide, and insecticide.

Table VII.1

GOLF COURSE MONITORING COMPOUNDS

Major Pesticides Used and Available Analytical Methods

Active Ingredient	Product(s)	Amt. used	% used[1]	Analytical Methods
HERBICIDES		40179	20.2%	
Chlorthal-dimethyl	Dacthal	12793	6.4%	EPA 608.2 (GC)
Bensulide	Betasan	6673	3.3%	EPA 636 (HPLC)
MCPP	Mecoprop	4880	2.5%	EPA 615, 1658 (deriv. & GC)
2,4-D	Trimec, Triamine	4858	2.4%	EPA 615, 1658 (deriv. & GC)
Benfluralin	Balon, Team	3799	1.9%	EPA 627, 1656 (GC)
INSECTICIDES		31195	15.6%	
Trichlorfon	Dylex, Proxol	8061	4.0%	EPA 1657 (GC)
Isofenphos	Oftanol	6408	3.2%	FDA 212.1, 232.3, 232.4 (GC)
Bendiocarb	Turcam, Ficam	6071	3.0%	EPA 639 (HPLC)
Chlorpyrifos	Dursban	5003	2.5%	EPA 622, 1657 (GC)
Carbaryl	Sevin	4115	2.1%	EPA 632 (HPLC)
FUNGICIDES		126919	63.6%	
Chlorothalonil	Daconil, Bravo	44670	22.4%	EPA 608.2, 1656 (GC)
Thiram	Spotrite, Bromosan	15714	7.9%	[as total CS_2] EPA 630, 630.1
EBDCs (Mancozeb, Maneb, Zineb)		13732	6.9%	[as total CS_2] EPA 630, 630.1
Iprodione	Chipco 26019	10213	5.1%	? (HPLC)
Propamocarb HCl		7459	3.7%	?
Anilazine	Dyrene	7052	3.5%	FDA 211.1
Triademefon	Bayleton	6183	3.1%	EPA 633, 1656 (GC)
Metalxyl	Ridomil, Subdue	5758	2.9%	FDA 232.3, 232.4
Benomyl	Benlate, Tersan 1991	3665	1.8%	?
Thiophanate	Cleary 3336	2911	1.5%	[canceled in US]
Fosetyl-Al	Aliette	2502	1.3%	[manufacturer ?] (GC)
Propiconazole	Banner, Tilt	2501	1.3%	[manufacturer ?] (GC)
GROWTH HORMONES		1159	0.58%	
Flurprimidol	Cutless	650	0.33%	?
Mifluidide	Embark	203	0.10%	?
Paclobutrazol	Clipper	79	0.04%	FDA 232.4
TOTAL		199451	100.0%	
High use materials		185953	93.2%	
Total w/ available analytical methods		155849	78.1%	
Total w/ available analytical methods (excluding EBDCs & Thiram as total Cs_2)		126403	63.4%	

[1] Pounds active ingredient (a.i.) reported
1990 NJDEPE/PCP Survey *Pesticide Use on Golf Courses*

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS

PESTICIDE	TRADENAME	CHEMICAL CLASS	DEGRADATION PRODUCT
ANILAZINE	DYRENE;	1,3,5-TRIAZINE;o-CHLOROANILINE	DICHLOROANILINE
BENDIOCARB	TURCAM WP; FICAM	CARBAMATE; METHYLCARBAMATE	DEALKYLATION AND/OR HYDROXYLATION
BENFLURALIN; BENEFIN	BENEFIN;BALAN;BENEFEX	DINITRO TRIFLUOROMETHYL ANILINE; TOLUIDINE	DEAMINATION; HYDROXYLATION; ?
BENSULIDE	BETASAN (EC; G)	OP; PHOSPHORODITHIOATE ESTER	OXO-ANALOGUE
BENTAZONE	BASAGRAN	BENZOTHIADIAZINONE; BENZOTHIADIAZOLE	2-NH2-N-ISOPROPYL-BENZAMIDE (STABLE,
CARBARYL	SEVIN(GRANULAR;4F;50W;85 SPRAY)	ABCARBAMATE; N-METHYLCARBAMATE, 1-NAPTHYL	CO2;1,4-NAPHTHOQUINONE;1-NAPTHOL(PHOTO)
CHLOROTHALONIL	DACONIL 2787; WP-75,SC,G,L	BENZONITRILE; CHLOROPHENYL-	2,4,5,6-Cl4-ISOPHTHALIMIDE
CHLORPYRIFOS	SURSBAN;LORSBAN 4E;WP	OP; ORGANOPHOSPHOROTHIOATE	3,5,6-TRICHLORO-2-PYRIDINOL
CHLORTHAL-DIMETHYL (DCPA)	DACTHAL	TETRACHLOROPHTHALATE	(TTA) TETRACHLOROPHTHALIC ACID DEGREDAT
2,4 - D			
DICHLOROANILINE	DEG. OF ANILAZINE & IPRODIONE	CHLOROAMINOBENZENE; CHLOROPHENYL-;AROMATIC	DEG. PRODUCT
ETHYLENETHIOUREA (ETU)	DEG.OF EBDC,MANEB,ZINEB,MANCOZ	UREA; THIOUREA; IMIDAZOLIDINETHIONE	DEG. PRODUCT
FENARIMOL	RUBIGAN EC;WP;SC	PYRIMIDINE(ClPHENYL)BENZHYDROL	MANY PHOTODEGREDATES IN WATER
IPRODIONE	CHIPCO 2601;ROVRAL WP,SC,HN	DICHLOROANILIDE; IMIDAZOLIDINE-DICARBOXIMIDE	DICHLOROANILINE:50%POST-APPLIC
ISAZOFOS	TRIUMPH,MIRAL,VICTOR;4EC,2%G	OP; ORGANOPHOSPHOROTHIOATE	5Cl-3OH-1-ISOPROPYL-1H-1,2,4-TRIAZOL
ISOFENPHOS			
MANEB	TERSAN; DITHANE M-22	Mn-EBDC;MANGANESE DITHIOCARBAMATE POLYMER	ETU; ETHYLENETHIOURA & DERIVS.
MBC (CARBENDAZIM)	DEG. OF THIOPHANATE & BENOMYL	BENZAMIDAZOLE CARBAMATE	FORMS SALTS WITH ACIDS
MECOPROP; MCPP (POTASSIUM SALT)	MCPP; MECOPROP	2-METHYL-4-CHLOROPHENOXY PROPIONIC ACID(KSALT	2-METHYL-4-CHLORO-PHENOL;MECOPROP-ME
METALAXYL	SUBDUE 2E(FOLIAR);RIDOMIL(SOIL	ACYLPHENYLALANINE; XYLYLALANINATE	N(diMe)PHENYL)N(2'OCH3ACETYL)ALANINE
OXADIAZON	RONSTAR EC,AL,GR	DICHLORPHENYL; (OXA) DIAZOLE-2-ONE	15 PHOTO DEG;N-NH2-BENZOXAZOLENE DER
PENDIMETHALIN			
PROPAMOCARB HCL (HYDROCHLORIDE)	BANOL	CARBAMATE; PROPYLCARBAMATE	NON-DEG.
PROPICONAZOLE	TILT EC; BANNER; ORBIT	CONAZOLE; TRIAZOLE-DICHLOROPHENYL DIOXOLAN	1,2,4-H-TRIAZOLE;TRIAZOLE ACETICACID
QUINTOZENE; PCNB	BRASSICOL; TERRACHLOR	CHLOROPHENYL; PENTACHLRORO; NITRO; BENZENE;AR	PENTACHLOROAMINOBENZENE;ANILINE
THIOPHANATE-METHYL	TOPSIN-M	CARBAMATE; PHENYLENE-THIOYL-BIS (CARBAMATE)	MBC (CARBENDAZIM) IN WATER
THIRAM	TERSAN 75; POLYRAM; SPOTRETE-F	DITHIOCARBAMATE-BIS(DIMETHYL-)DISULFIDE	ETU ETHYLENETHIOUREA (MAJOR DEG.);EU
TRIADIMEFON	BAYLETON	CONAZOLE; CHLOROPHENOXY-TRIAZOL-YL-BUTANONE	TRIAZOLE;HYDROXYTRIAZOLE;BAYTAN(T1/2
TRICHLORFON			
TRICHLORO-2-PYRIDINOL	DEG.OF TRICLOPYR; CHLORPYRIFOS	TRICHLORO PYRIDINE	DEG. PRODUCT
TRICLOPYR	TURFLON EC; GARLON EC	PYRIDYLOXYACETIC ACID; TRICHLORO PYRIDINE;	3,5,6-TRICHLORO-2-PYRIDINOL(AC)

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS (CONTINUED)

PESTICIDE	METABOLITE	USE	SOIL_INC	MW	MELTING POINT
ANILAZINE	AMINO/THIO-SUBST of Cl(TRIAZIN	F;FOLIAR; NONSYSTEMIC;2.5gAI/l	0"	275.5	159 C (BC)
BENDIOCARB	NC 7312; MOBILE	I; FOLIAR; SOIL INCORP.	0-0.5"	223.2	128-130 C
BENFLURALIN; BENEFIN		H; EC,G;PREEMERG.@1.35kg AI/ha	0"	335.28	65-66.5 C (AC)
BENSULIDE		H; PREEMERGE;SURF;11-22kgAI/ha	0"	397.5(BC	34.4 C (BC
BENTAZONE		CONTACT HERB; 1-2.2 kg/450l/ha	0"	240.3	137-139 C.
CARBARYL	1-NAPHTHOL; 1-NAPHTHYL-N- -HYDROXYMI;	CONTACT,SL.SYSTEMIC;UP TO 2kg AI/ha		201.22	(OL) 142 C. (BC,OL)
CHLOROTHALONIL	4-OH-256-Cl3-ISOPHTHALONITRILE	F; FOLIAR,SURF;0.46-1.8gAI/sq.	0-0.5"	265.91	250-251 C
CHLORPYRIFOS	3,5,6-TRICHLORO-2-PYRIDINOL	I; FOLIAR; SOIL	0-0.5"	350.58	41.5-43.5 C
CHLORTHAL-DIMETHYL (DCPA)	METHYL TETRACHLOROTEREPHTHALATE	H:PREEMERGENCE; W-75 (<0.24% HCN)	0-0.5"	332	
2,4 - D					
DICHLOROANILINE				162.03	71-72 C (MERCK)
ETHYLENETHIOUREA (ETU)				102.17 M	203-204 C.(MERCK)
FENARIMOL		F; FOLIAR; 1-9 g AI/hl (BC	0"	331.2	117-119 C
IPRODIONE		F; SURF.; 3-12 kg AI/ha	0"	330.2	136 C
ISAZOFOS		I&N; SURF.; 1-2lb AI/A	0"; IRRIGATE	313.7	BP=100C @0.001mmHg
ISOFENPHOS					
MANEB	PLANT:ETHYLENETHIOUREA	F; FOLIAR; @ 3.6 kg AI/ha	0"(x=Mn;y=Zn	265x+65y	192-204C (DECOMPOSES
MBC (CARBENDAZIM)		F; SYSTEMIC; @400 g/ha	0"	191.2	302-307C (DECOMPOSES
MECOPROP; MCPP (POTASSIUM SALT)		H;SYST.GROWTH-REG; 3.9kg/ha	0";AQ&FOREST	214.6	94-95 C. (AC)
METALAXYL		F; SYSTEMIC;vs.AIR&SOIL BORNE	0"	279.3	71.8-72.3 C
OXADIAZON		H; 2-4kg AI/ha; PRE-EMERG.	0"	345.2	88-90 C
PENDIMETHALIN					
PROPAMOCARB HCL (HYDROCHLORIDE)		F; SYSTEMIC;SOIL/ROOT;FOLIAR	0-0.5"	225(188)	45-55 C (BC)
PROPICONAZOLE		F; SYSTEMIC;FOLIAR;250g AI/ha	0"	342.2	BP=95C TECHNICAL (FC
QUINTOZENE; PCNB	PENTACHLOROANAILINE;METHYLTHIO	F; SEED OR SOIL TRMT.	0"-0.5"	295.3	146 C. (BC)
THIOPHANATE-METHYL	PLANT -> MBC (CARBENDAZIM)	F; 30-50g AI/hl	0"	342.4(BC	172 C. (DECOMPOSES)
THIRAM	PLANT->ETU->THIURAM MONOSULFID	F; FOLIAR OR SEED; FC,WP,DUSTS	0"	240.4	146C.TECH.(BC);155C.
TRIADIMEFON		F; SYSTEMIC&PROT;125-250gAI/ha	0"	293.8(BC	82.3 C. (BC)
TRICHLORFON					
TRICHLORO-2-PYRIDINOL					
TRICLOPYR	" METHOXY-PYRIDINE;TCP SOIL T1	H;FOL&ROOT SYSTEMIC;1-4-8kg/ha	0"	256.5	148-150 C. (BC)

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS (CONTINUED)

PESTICIDE	KOW	K_DISTRIB	KD_SAND	KD_LOAM
ANILAZINE	1020 (BC)			
BENDIOCARB	50 (SC)	f(SOIL)	Sand S= 0.14; Sd= 0.6 (OL)	CL= 1.14 (OL)
BENFLURALIN; BENEFIN	195,000 (AC,OL)		Sd(pH7.7)= 27	ClLm (pH6.9)= 117
BENSULIDE	16,500 (BC			
BENTAZONE	0.35 (BC)		LmS=0.45 (OL)	LmS=0.45;Heavy Cl=0.176;Cl=3.0
CARBARYL	1.38 (OL)			
CHLOROTHALONIL	758.6 (OL		Sd= 3	Si= 29
CHLORPYRIFOS	50,119(OL);9.1E4(TDS			SiLm2%OC=99.7; Lm6%OC=49.9(OL
CHLORTHAL-DIMETHYL (DCPA)				
2,4 - D				
DICHLOROANILINE				
ETHYLENETHIOUREA (ETU)				
FENARIMOL	2,512 (OL); 4,900(BC			SdLm Kd=6.35 (OL)
IPRODIONE	1,260 (BC)			
ISAZOFOS	6,309 (OL)		0.27(OL)	SiLm=2.37; Cl=3.92 (OL)
ISOFENPHOS				
MANEB	0.205 (OL)			
MBC (CARBENDAZIM)	36 (BC)			
MECOPROP; MCPP (POTASSIUM SALT)	1E-7 (OL); 1.26 @pH7		0.19 (OL); SdLm= 0.29	SiLm= 0.68; SiClLm= 0.43
METALAXYL			Sd=0.43 (OL)	SdLmCl=1.4 (OL)
OXADIAZON	63,100 (BC)			
PENDIMETHALIN				
PROPAMOCARB HCL (HYDROCHLORIDE)	0.0018 (BC)			
PROPICONAZOLE				
QUINTOZENE; PCNB				
THIOPHANATE-METHYL	25 (BC)	1.2 (BC)		
THIRAM				
TRIADIMEFON	1,510 (BC); 977(OL)	3.5-9(OL)	3.5-5.9 (OL)	5.9-9.3 (OL)
TRICHLORFON				
TRICHLORO-2-PYRIDINOL				
TRICLOPYR	4.9 (OL)		0.975 (OL)	SiLm=0.165;SdLm=0.57;ClLm=0.73

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS (CONTINUED)

PESTICIDE	K_OC_SOIL	PHOTO_SOIL	PHOTO_H2O	VAPOR PRESSURE	WATER SOLUBILITY
ANILAZINE	1000(SC ESTIMATE)			820 nPa (BC)	8 mg/l (BC)
BENDIOCARB	570	7.8 hr.		5E-6mm;3.5E-5mm(SCS);4.6mPa(OL	40ppm (EX/M/AC/SCS)
BENFLURALIN; BENEFIN	11,000 (OL)	UV DEG.	5.5 hrs.	3.7 mPa (VOLATILE)	0.1 ppm (OL)
BENSULIDE	1000est(SC	REL.STABLE		<133uPa@20C(EX;8E-7mmHg(SC	25mg/l (OL)
BENTAZONE		STABLE	DEG.<24 hr	0.46 mPa (BC)	500 mg/kg
CARBARYL	200 (OL)		45hr@pH5(OL	1.2 E -6 Torr (OL)	120 mg/l @20C.(OL)
CHLOROTHALONIL	1380(OL,SC	STABLE		<1.3Pa@40C(AC);2E-6mm@25(OL	0.6mg/l(REFS);1.2(OL
CHLORPYRIFOS	6070(SC-GL	3-6d.(OL		2.5mPA(AC);1.7E5mmHg(SC; VOLTL	2 mg/L @25C. (AC)
CHLORTHAL-DIMETHYL (DCPA)		STABLE (OL)	STABLE (OL)	2.1 E-6 TORR (OL)	0.5 ppm (OL)
2,4 - D					
DICHLOROANILINE					
ETHYLENETHIOUREA (ETU)		STABLE	STABLE		20 ppm (OL)
FENARIMOL	2,000(OL); 600(SC)	STABLE		2.2E-7mmHg(SC); 0.013mPa(BC)	13.7 mg/l (SC,BC)
IPRODIONE	700(SC); EST.EPA=1K	DEG.1-2 wk	DEG. 3-7d.	<1E-7mmHg(SC); <0.133mPa(BC)	13 mg/l(BC,OL)
ISAZOFOS	*100 (SC)*			*4.3 mPa (BC); 8.7E-5 mm Hg(SC)*	*250mg/L(*);69mg/l(SC*
ISOFENPHOS					
MANEB		STABLE		NEGLIGIBLE	0.5ppmOL; 160 mg/lBC maneb chelates 8mg/l@pH7;28mg/l@pH4
MBC (CARBENDAZIM)		STABLE		<0.09mPa(BC)	
MECOPROP; MCPP (POTASSIUM SALT)				5E-6mmHg (OL); 0.3mPa (BC)	620 ppm (OL,BC)
METALAXYL	50 (SC); 35(GL)			0.293mPa@20C(AC);5.6E-6mmHg(SC	7.1g/l(AC,BC,GL)
OXADIAZON	3200 (SC)			<0.133mPa(AC,BC); 1E-6mmHg(SC)	0.7mg/L@20C(AC,BC,SC
PENDIMETHALIN					
PROPAMOCARB HCL (HYDROCHLORIDE)	1E+6 NON-SALT FORM	STABLE	STABLE	c.0mmHg(SC;0.8mPa(BC;800mPa(AC	867g/l(BC,FC,AC)SALT
PROPICONAZOLE	100 (EST.OL);1000(SC	STABLE	DEG.in 1d.	0.13mPa@20C(AC);4.2E-7mmHg(SC)	110 mg/l (FC)
QUINTOZENE; PCNB				6.6 mPa (VOLATILIZATION.LOSS)	0.44 mg/l (AC)
THIOPHANATE-METHYL	1830(SC)			<1E-7mmHg(SC)	3.5mg/l(SC);26.6(BC)
THIRAM	383 (OL)			NEGLIGIBLE(BC)	c. 30 mg/l (AC,OL,BC
TRIADIMEFON	1E+7(EST.OL); 300(SC	STABLE	10-12 hrs.	1.5E-8mmHg(SC);	260mg/l(BC; 71.5 (SC
TRICHLORFON					
TRICHLORO-2-PYRIDINOL					
TRICLOPYR	SiLm=15; ClLm=37(OL)	<12 hrs.		0.168 mPA (AC)	440 mg/L (AC)

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS (continued)

PESTICIDE	SOIL_DR	SOIL HALF-LIFE	WATER HALF-LIFE	PLANT_DR	PLANT HALF-LIFE
ANILAZINE		12 hr; (DAMPSOIL)	730-790hr @ pH4-7; 22 hr@ pH9		
BENDIOCARB	Lm2-4wk;	SdLm1-3d(BC;5d(SC;Lm2-3wk(OL	46d.@pH5;48hr.@pH7;44 min@pH9		degrades rapid.
BENFLURALIN; BENEFIN		2.5 - 8.2 wks. (OL)	1-2 hrs. (OL)		
BENSULIDE	0.014-0.01	120-140d.LmSd;BC,SC;120-180d(O	REL.STABLE		
BENTAZONE			V.STABLE TO ACID/BASE HYDROLYS		RAPID METAB.
CARBARYL		7-17d.LmSd@F.C,;7-14d.SdLm@25C.	(30d.@pH6.7;12d.@pH7.2;4d. NATURAL WATER; 10D.DIST.H2O(OL)		
CHLOROTHALONIL	25-56 d.	f(H2O&T);SdLm11d; Lm15d; Si37d	STABLE>10WKS(FS		10d(Gleams)
CHLORPYRIFOS		f(SOIL);11-141d; 2.5wk@10ppm(O	72d.@pH5+pH7;16d.@pH9; f(pH,OM		12hr(corn)3.3 d
CHLORTHAL-DIMETHYL (DCPA)		2-4 wk.72%Cl & 25%Si; 4-7 wk. 60%Sd (OL)			
2,4 - D					
DICHLOROANILINE					
ETHYLENETHIOUREA (ETU)		29 - 35 d.	STABLE; anaerobic.149 d.(OL)		
FENARIMOL		1yr.(2mo.-2yr.f(H2O at APPLIC.	STABLE;PHOTO-UV/H2O H.L.= 4hrs		
IPRODIONE		14d.(SC);15-45d.(OL); f(pH,T.)	ACID-STABLE; 20d.@pH6;1d.@pH9		
ISAZOFOS		SdLm=34d(SC); ClLm=60-90d.(OL)	85d@pH5;48d@pH7;19d@pH9(OLcalc		
ISOFENPHOS					
MANEB		LmSd: DT50= c. 25 d.(BC)	DT50= <24 hrs @ pH 5-9		
MBC (CARBENDAZIM)		1-5 mos. approx. (BC)	>35d.@ pH5-7; 124d. @pH 9 (BC)		
MECOPROP; MCPP (POTASSIUM SALT)		7-9 d. (SdLm,Cl,ClLm (OL)	REL. STABLE		
METALAXYL		70d.(SC); 25d.(GL)	>200d.@pH1; 115d@pH9; 12d.pH10		10 d.(GL)
OXADIAZON		60d.(SC); c.90d.(BC)			
PENDIMETHALIN					
PROPAMOCARB HCL (HYDROCHLORIDE)		30d(SC;10-27d(SC;MICROB.ADAPT.	ACID STABLE		
PROPICONAZOLE		70d.(OL); 110d.(SC)	5d;ACID STABLE;IRRIG.H2O:1d(OL		
QUINTOZENE; PCNB		VERY STABLE IN SOIL (AC)	STABLE IN ACID&N; DEG.IN BASE		
THIOPHANATE-METHYL		10d. approx.(BC); < 1 d.(OL)	STABLE<pH5;AQ.DEG;Cu COMPLEX		DEG.TO MBC
THIRAM		pH6: 1-2 wk; pH7: 4-5 wk(OL);	DEG.in AIR, HEAT, WATER		DEG. TO ETU (BC
TRIADIMEFON		6d=SiCl,18d=SLm (OL); 26d.(SC)	>1 yr. @ ALL pH		
TRICHLORFON					
TRICHLORO-2-PYRIDINOL					
TRICLOPYR		46 d. (non-leaching conditions			

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS (continued)

PESTICIDE	PLANT WASHOFF %	FIELD PERSISTENCE	PERS. @ DEPTH & TIME	MOBILITY	SURFACE (1-5)
ANILAZINE					
BENDIOCARB		0-6"soil @14-30d.Function(soil		Rf=0.59Lm; Rf=0.83Sd (OL)	
BENFLURALIN; BENEFIN		4-8 mos. RES. ACTIVITY			LARGE
BENSULIDE		0-2"SOIL @ 4-12mos.	4-8" @ 7 d.	NON-MOBILE IN SOIL	
BENTAZONE		< 6 WKS.		94%LEACHEDc12"H2O;MOBILEinRUNO	HIGH(OL)
CARBARYL		1.2ppm -> 0.45(8d), 0.2(30d), .01(68d)(OL)	<1d.SOIL,H2O,SED.<1PPM	Rf=0.2-0.46 SiLm,MUCK 8%OM-SdLm 1.5%OM	CV.LARGE (90%in1
CHLOROTHALONIL	5%			f(%SILT);NOT%OM; Sd.MOD;Si.LOW	LARGE
CHLORPYRIFOS	65%	VOLATILE & WATER-PHOTOLYSIS	TOP 2" SOIL	LOWin>1%OC;LEACH in BASIC SOIL	LARGE
CHLORTHAL-DIMETHYL (DCPA)		DT1/2 >13 wk. SdLm (OL)		Rf=0.0(no UV); Rf=0.75-0.9 (after light) (OL)	<1%DCPA AND MTP LEACH
2,4 - D					
DICHLOROANILINE					
ETHYLENETHIOUREA (ETU)				Rf=0.61; MED. MOBILITY (HA/EPA	
FENARIMOL		FUNCTION OF WATER AFTER APPLIC		Rf=0.02-0.05; NOT f(OM%, pH)	MEDIUM
IPRODIONE		FUNCTION OF pH AND TEMPERATURE	TOP 10 cm. SOIL	MOBILE IN FINE, ACID SOILS	MEDIUM
ISAZOFOS			6-51% LEACHES	MOBILE; FISH KILL POTENTIAL;	
ISOFENPHOS					
MANEB		DECOMP.BY AIR, MOISTURE, HEAT		ETU-MOBIL DEGREDATE	LRG(TERSAN);MED
MBC (CARBENDAZIM)		DT50=1-5 mos. (BC)		MBC IS REL.MOBILE	
MECOPROP; MCPP (POTASSIUM SALT)					SMALL
METALAXYL	70%	FORMED DEGREDATE	99% @ 6-12cm SdClLm	V.HIGH in SAND (70-90%LEACHES)	SMALL
OXADIAZON			96% @ 5cm. @ 16d.	LOW MOBILITY IN SOIL	
PENDIMETHALIN					
PROPAMOCARB HCL (HYDROCHLORIDE)		ACTIV.3-4WK;MICROB.ADAPT.5-56d		IMMOBILE IN SOIL (OL)	
PROPICONAZOLE				HIGH MOBILITY IN SAND	MEDIUM
QUINTOZENE; PCNB		PERSISTENT; (4-10 mos.(AC))		LOW MOBILITY IN SOIL	
THIOPHANATE-METHYL		SEE MBC; < 1 d. in SdLm, ClLm		PARENT & MBC DEG. ARE MOBILE	SMALL
THIRAM		THIOPH. 1-2 wks.ALL SOILS (OL)			LARGE
TRIADIMEFON		0-6"@5-8mos(Lm); 6-12"@9-29mos	0-6" sand @ 5mos.	AGED RES.LEACH; Rf=0.16-0.28 (	MEDIUM
TRICHLORFON					
TRICHLORO-2-PYRIDINOL					
TRICLOPYR			>6" @ >20 d.		

TABLE VII.2 PESTICIDES - ENVIRONMENTAL FATE CHARACTERISTICS (continued)

PESTICIDE	LEACHING (1-5)
ANILAZINE	MOBILE
BENDIOCARB	
BENFLURALIN; BENEFIN	SMALL
BENSULIDE	
BENTAZONE	HIGH(OL)
CARBARYL	
CHLOROTHALONIL	FROM NON-SILTY
CHLORPYRIFOS	FROM BASIC SOIL
CHLORTHAL-DIMETHYL (DCPA)	
2,4 - D	
DICHLOROANILINE	
ETHYLENETHIOUREA (ETU)	
FENARIMOL	SMALL
IPRODIONE	FROM ACID SOIL
ISAZOFOS	LARGE
ISOFENPHOS	
MANEB	SMALL
MBC (CARBENDAZIM)	
MECOPROP; MCPP (POTASSIUM SALT)	LARGE
METALAXYL	MEDIUM; Sd.HIGH
OXADIAZON	SMALL (OL)
PENDIMETHALIN	
PROPAMOCARB HCL (HYDROCHLORIDE)	SMALL (OL)
PROPICONAZOLE	MEDIUM; Sd.HIGH
QUINTOZENE; PCNB	
THIOPHANATE-METHYL	MEDIUM
THIRAM	SMALL
TRIADIMEFON	MEDIUM
TRICHLORFON	
TRICHLORO-2-PYRIDINOL	
TRICLOPYR	

Table VII.2 Pesticides - Environmental Fate Characteristics (continued)

GROUND WATER LEACHING CRITERIA

Water Solubility:	S	>	30 mg/l (ppm)
Distribution Coefficient:	Kd	<	5
Adsorption Coefficient:	Dads	<	5
Soil (Organic Carbon) Distribution Coefficient:	Kox	<	300
Photolysis Half-life (UV):	T(½)	>	1 week
Hydrolysis Half-life:	T(½)	>	25 weeks
Soil Half Life:	T(½)	>	3 weeks (Aerobic metabolism)
Persistence:		>	12 weeks

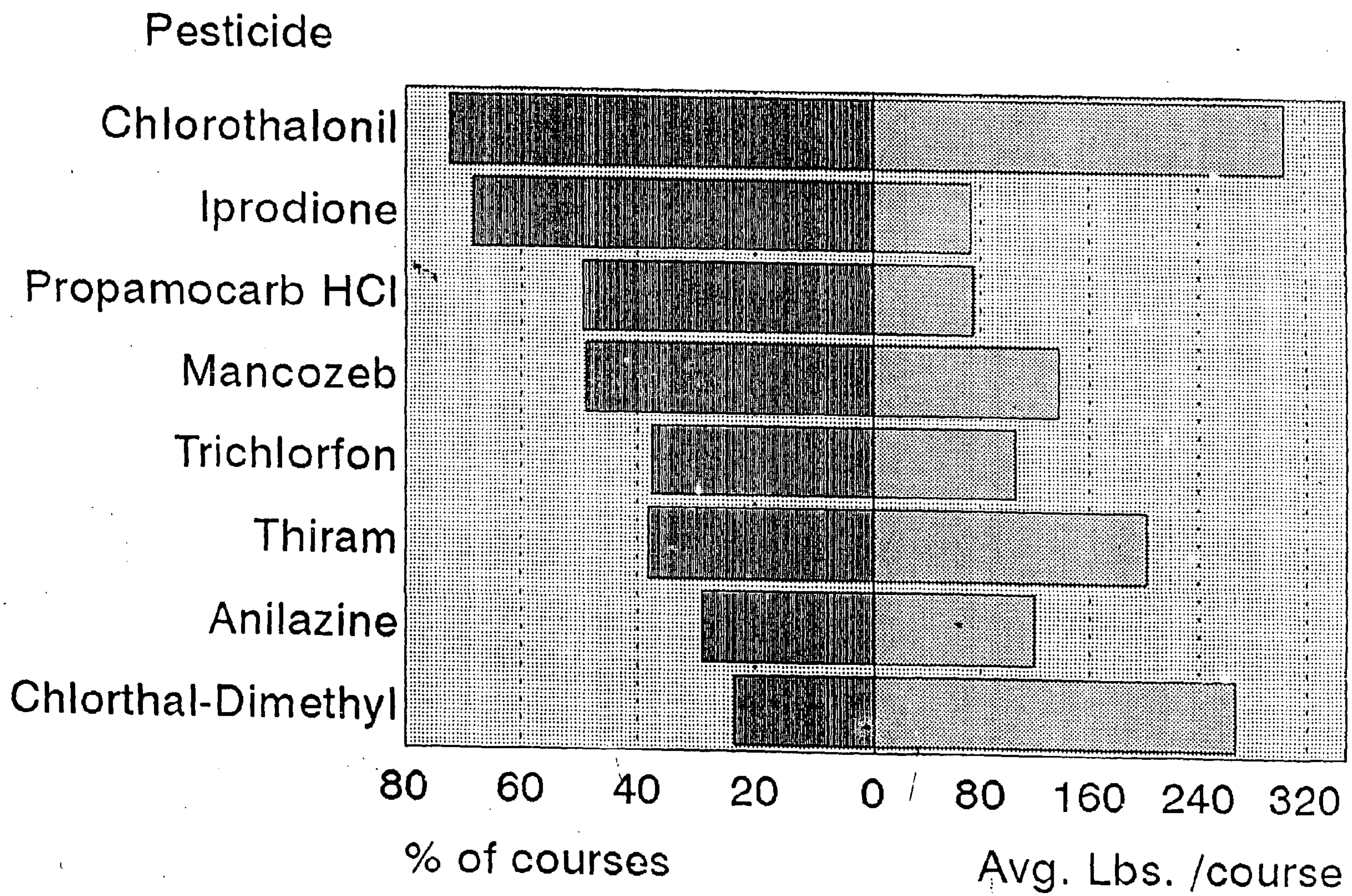
ADDITIONAL PARAMETERS

Bioconcentration Factor (BCF)
Toxicity

Pesticide Use (amount and site)
GW/aquifer/well sensitivity

Pesticide Use on New Jersey Golf Courses Frequency of use

Figure VII.1 Frequency of Pesticide Use on New Jersey Golf Courses



Chapter 8. Recycled Materials

The use of recycled materials in the construction of a golf course is encouraged in order to conserve natural resources and to decrease society's production of solid wastes. Some specifics concerning the use of recycled material in the construction of a golf course are:

A. New Jersey's Department of Transportation allows I-5 aggregate used in roadway subbase construction to be produced from recycled concrete aggregate. For information concerning DOT's regulations please call the Department of Transportation at (609) 530-2098.

B. The Bureau of Market Development, Source Reduction, and County Planning (BMDSR&CP) has been encouraging the use of recycled materials under the condition that the effectiveness of the recycled material has been fully examined and considered. Recycled materials may be applicable for various structures at the golf courses including cart paths, some structures requiring wood, drainage applications, etc. For a list of recycled materials suitable for such applications and for information concering the substitution of virgin materials for recycled materials in the construction and maintenance of golf courses, please call BSRMD&CP at (609) 530-8207.

C. The DSWM also recommends that whenever possible, recycled materials be utilized in the construction and maintenance of the golf course. Potential applications include the following:

   a. Recycled plastic pilings and structural building components used in cartpaths or for landscaping throughout the golfcourse particularly in wet areas;

   b. Recycled plastic automobile tire stops in parking lots;

   c. Recycled concrete aggregate or asphalt millings in parking lot or cart path construction;

   d. Recycled wood chips/mulch used in landscaping;

   e. Sludge derived products (pelletized fertilizers, liming agents, and compost) incorporated into the management of a golf course. (Note: Because sludge derived products are regulated under certain situations, further information should be obtained from the Residuals Management Permits Section at (609) 633-3823.)

D. The National Standard Plumbing Code was rcently amended to allow the use of "crushed-recycled glass aggregate" in the construction of subsoil drains around the perimeter of all buildings having basements, cellars, or crawl spaces or floors below grade. (See appendix E)

E. Other recycled materials which may have potential use at a golf course for drainage purposes are currently being tested. The study results will be available to the public when the testing has been completed. The candidate recycled materials are crushed container glass (e.g. green and mixed color glass) and recycled concrete aggregate. Potential areas for application of these recycled materials would be the subsurface drainage layer of greens.

F. For recyclable solid waste generated at the golf course, such as tree stumps, the Division of Solid Waste Management (DSWM) advises that regulation at NJAC 7:26A-1.1 et seq. require it be sent to one of the State's approved recycling centers. A current list of these centers and the materials they accept for recycling can be obtained by calling DSWM at (609) 530-8591.

Chapter 9. Regulatory Authority

Although other statutes are not excluded in determining the statutory and regulatory authority by which golf course construction is regulated in New Jersey, four state statutes related to the Land Use Regulation Program can be applied depending on the location and overall scope of the project. Each of the four statutes, as explained below, requires that specific findings be made to ensure that the resources of the area, including water quality, are not negatively impacted.

I. **The Coastal Area Facility Review Act, N.J.S.A.13:19-1 et seq.** requires that certain sized facilities within a designated coastal area extending South along the coast from Middlesex/Monmouth to Salem/Cumberland counties receive a permit prior to the commencement of construction.

While Golf Courses per se, are not one of the regulated activities, they are often associated with development of greater than 25 or more dwelling units which are regulated under the CAFRA Statute. Another measure also used in determining if a CAFRA Permit is required is proposed length of sewer, road construction or parking, which may be associated with golf course construction.

Outside of the designated CAFRA area, development including golf courses within 100-500 feet of a tidal waterway is regulated by the **Waterfront Development Law N.J.S.A. 12:5-3.**

In each case, under either the CAFRA or the Waterfront Development Law an application is reviewed for consistency with the **Rules on Coastal Zone Management N.J.A.C. 7:7E.**

These rules contain specific and detailed parameters set out in a framework of Location, Use and Resource Policies. Some commonly encountered policies likely to pertain to golf course construction and management are as follows: **Endangered and Threatened Wildlife or Vegetation N.J.A.C. 7:7E-3.38 and Critical Wildlife Habitat, N.J.A.C. 7:7E-3.38,** are certain habitats, ecotones or edges between two types of habitats, which deserve protection from development which would adversely impact these areas.

Water Quality, N.J.A.C. 7:7E-8.4, requires that developments not violate water quality requirements under the Clean Water Act and recognizes that most of New Jersey's natural resources are directly affected by the quality of their surface and ground waters.

Surface and Groundwater Use, N.J.A.C. 7:7E-8.5 and 6 require that any proposed work which shall utilize either surface or ground water would not exceed the ground water capacity nor alter the present surface water flow patterns or degrade the quality of the resource.

Stormwater Runoff, N.J.A.C. 7:7E-8.7 pertains to the maximization of surface water recharge utilizing best available management practices to ensure long term water quality protection. Regulated golf courses are required to provide a series of assurances through ground and surface water monitoring that no degradation of the water resources will be experienced.

Vegetation, N.J.A.C. 7:7E-8.8 entails the careful siting of a facility to minimize the physical disturbance of a site and maximize the retention of existing plant material. Uses of indigenous shrub and tree species are promoted through this policy.

Important Wildlife Habitat, N.J.A.C. 7:7E-8.9, habitats, which provide needed food and cover, are dependent on good water quality to ensure maximum wildlife productivity. Any development that alters these sites without management techniques which minimize the impact, is discouraged.

The Buffers and Compatibility of Uses Policy, N.J.A.C. 7:7E-8.13, identifies the important function of set aside or buffer areas in order to protect the integrity of significant natural resources and current land uses.

II. The Flood Hazard Area Control Act, N.J.S.A. 58:16A-50, requires a stream encroachment permit for certain activities within the flood hazard area. The Rules and Regulations Governing the Flood Hazard Area are identified as N.J.A.C. 7:13-1.1 et.seq. The purpose and scope of the Act are as follows:

A. The general purpose of the Act is to control construction and other developmental activities in stream channels and in areas subject to flooding in order to avoid or mitigate detrimental effects of such activities.

B. The regulation's intention is to minimize losses and damage to public and private property caused by land uses and channel modifications which, at times of flood, increase flood heights and/or velocities; to safeguard the public from the dangers and damages caused by materials being swept onto nearby or downstream lands; to protect and enhance the public's health and welfare by minimizing the degradation of stream water quality from point and non-point pollution sources, and to protect wildlife and fisheries by preserving and enhancing water quality and the environment of the stream channel and floodplain.

C. Without proper controls, stream encroachments may adversely affect the flood carrying capacity of the stream, may create new facilities within areas subject to floods, may reduce natural flood storage that the flood plain provides, and may result in increased sedimentation, erosion, or other environmental damage. Any stream encroachment must conform to certain criteria which depend upon the characteristics of the area and the type of activity involved.

The Stream Encroachment Permit is required whether the work is permanent or temporary. Examples of regulated work include removal of vegetation along a stream bank or a stream crossing, the construction of culverts, outfall structures, detention basins, stormwater discharge, wetland fill, grading, etc.

The Flood Hazard Area regulations apply to all stream encroachments within the flood hazard area and the 100 year flood plains within the State of New Jersey, at locations having a drainage area of over 50 acres and all Projects of Special Concern as defined in N.J.A.C. 7:13-5. The Regulations also apply to all perennial trout associated streams.

A Project of Special Concern is a classification for a stream encroachment project which, because of its adverse impacts, will be subject to the special conditions described in N.J.A.C. 7:13-5. Activities which are proposed on a perennial stream that will channelize that stream for over 100 feet, disturb a distance over 300 feet on either side of a bridge or culvert, or remove 6,000 sq ft of existing woodlands within 25 feet of the banks will be classified as a project of special concern. In addition, stream encroachment projects which the Department determines would be likely to produce serious adverse effects on the water resources of the State shall also be handled as Projects of Special Concern. Such effects shall include, but are not limited to the following:

- Potential serious adverse effects on the biota of the stream, the adjoining wetlands, or on sites where dredged spoils are to be disposed of including, but not limited to rare or endangered species.

- Potential serious degradation of water quality below the Department's Surface Water Quality Standards.

- Potential serious adverse effects on water resources including, but not limited to, adverse effects on potable water supplies, flooding, drainage, channel stability, navigation, energy production, municipal, industrial, or agricultural water supplies, fisheries or recreation. Such impacts include damage to potential as well as existing water users.

Projects of Special Concern always include stream encroachment applications requiring the loss of more than 6,000 square feet of vegetation within 50 feet of the banks of trout associated streams or the construction of low dams across perennial, trout associated streams, except for the reconstruction or repair of existing dams. In addition, stream encroachment projects causing exposure of acid producing deposits along more than 50 feet of stream channel, if the drainage area of the stream is greater than 50 acres, will also be classified as a Project of Special Concern. However, this applies to smaller streams if the stream is trout associated and if the stream is perennial.

These regulations also do not apply to activities along the Delaware and the Raritan Canal except insofar as such activities affecting streams that flow into, over, under, or parallel to the canal; nor do they apply to most tidal waterbodies where a Waterfront Development Permit is issued.

III. Freshwater Wetlands Protection Act (N.J.S.A. 13:9B-1 et seq.)

Freshwater wetlands are protected under the Freshwater Wetlands Protection Act because it has been determined that: freshwater wetlands protect and preserve drinking water supplies by serving to purify surface water and ground water resources; freshwater wetlands provide a natural means of flood and storm damage protection, and thereby prevent the loss of life and property through the absorption and storage of water during high runoff periods and the reduction of flood crests; freshwater wetlands serve as a transition zone between dry land and water courses, thereby retarding soil erosion; freshwater wetlands provide essential breeding, spawning, nesting and wintering habitats for a major portion of the State's fish and wildlife, including migrating birds, endangered species, and commercially and recreationally important wildlife; and that freshwater wetlands maintain a critical baseflow to surface waters through the gradual release of stored flood waters and ground water, particularly during drought periods.

Transition (or buffer) areas are regulated under the Freshwater Wetlands Protection Act because it has been determined that a transition area serves as an ecological transition zone from uplands to freshwater wetlands. The transition area is an integral portion of the freshwater wetlands ecosystem, providing temporary refuge for freshwater wetland fauna during high water episodes, critical habitat for animals dependent upon but not resident in freshwater wetlands. Such an area provides slight variations of freshwater wetland boundaries over time due to hydrologic or climatologic effect; and a sediment and stormwater control zone to reduce the impacts of development upon freshwater wetlands and freshwater wetland species.

Golf courses are not specifically listed under the Freshwater Wetlands Protection Act as a regulated activity. They end up being regulated when the applicant proposes a regulated activity within a freshwater wetlands or transition area (wetlands buffer). The following is a list of regulated activities within wetlands as set forth in N.J.A.C. 7:7A-2.3 and the list of regulated activities in transition areas as set forth in N.J.A.C. 7:7A-6.2:

A. Wetlands

1. The removal, excavation, disturbance or dredging of soil, sand, gravel, or aggregate material of any kind;
2. The drainage or disturbance of the water level or water table;
3. The dumping, discharging or filling with any materials;
4. The placing of obstructions;
5. The destruction of plant life which would alter the character of a freshwater wetland, including the cutting of trees except for the approved harvesting of forest products pursuant to N.J.A.C. 7:7A-2.7(b); and
6. The term "regulated activity" shall also mean the discharge of dredged or fill material into State open waters.

B. Transition Area

1. Removal, excavation, or disturbance of the soil;
2. Dumping or filling with any materials;
3. Erection of structures;
4. Placement of pavements; and

5. Destruction of plant life which would alter the existing pattern of vegetation.

An example of a regulated activity commonly associated with a golf course is the construction of a stormwater outfall structure in the wetlands. These outfalls usually discharge waters from a "water hazard area" or detention/retention basin located on the golf course. In reviewing a freshwater wetland application, the Department would consider disturbance of wetlands, transition areas, state open waters, water quality and hydrological changes.

In summary, wetlands and transition areas perform essential functions which range from acting as ground water recharge zones to habitat for numerous flora and fauna. Protection of these resources is mandated by the Act and when issuing a permit to disturb these areas the State must be confident that their long term functions have not been sacrificed for development. Therefore monitoring of project sites after construction allows the State two main pieces of information. One is the short-term verification of the success of the stormwater management plan. The other is the collection of data to assess the long-term impacts of development on these sensitive resources. With this information the Program is better able to appraise the impacts a proposed project may have on the wetlands and transition areas and the resources associated with them.

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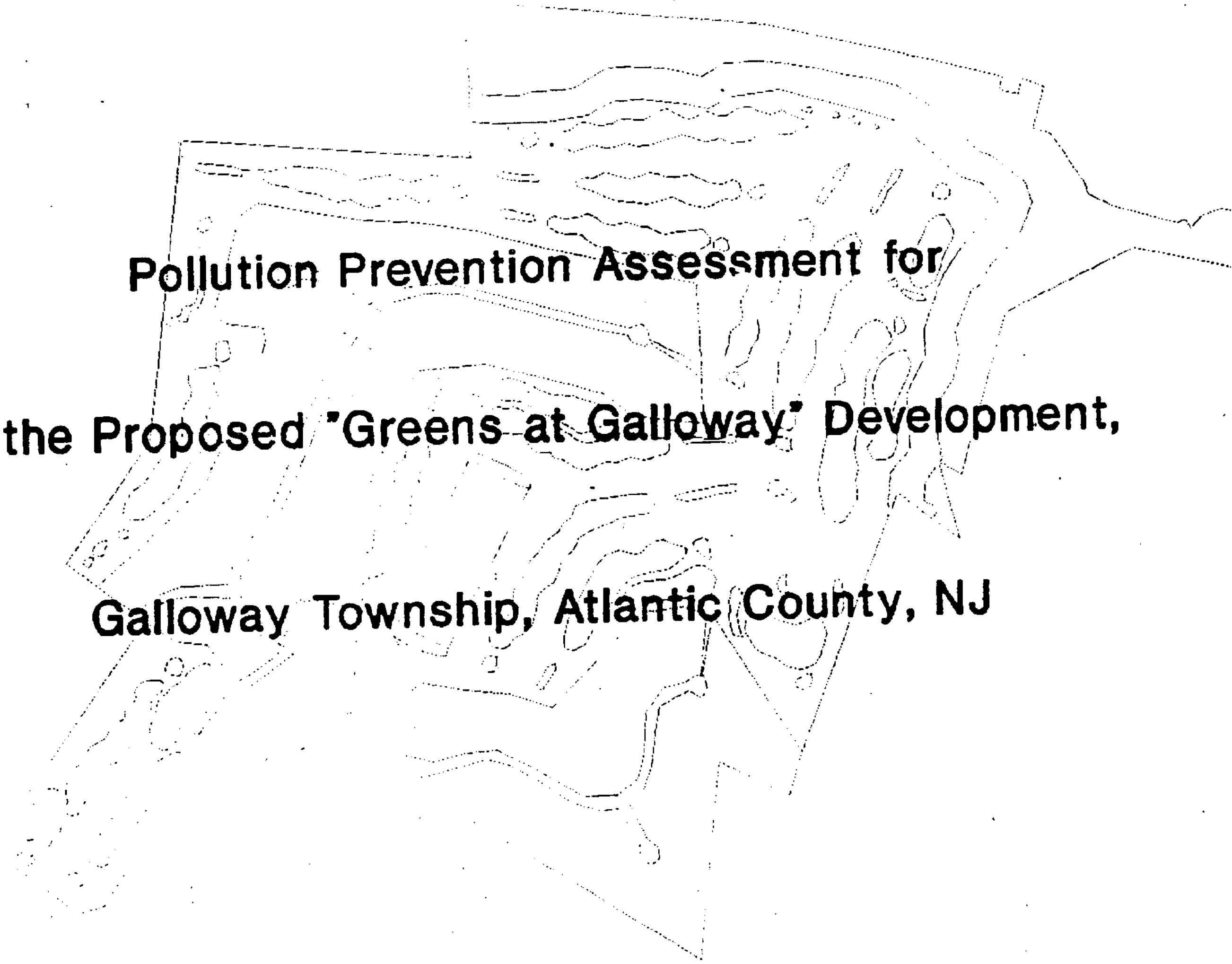
Appendix A.

Example of Modeling Simulation for a Proposed Golf Course

Pollution Prevention Assessment for the Proposed "Greens at Galloway" Development, Galloway Township, Atlantic County, NJ



Prepared by

Office of Regulatory Policy

Standards and Systems Analysis Program

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Tom Cosmas, Senior Environmental Specialist - Soil and Nutrient Modeling

Margaret Elsishans, Senior Environmental Specialist - Pesticide Modeling.

Land Use Regulation Program - Providing Site Plan and related Information.

Standards and Criteria Section, Standards and Systems Analyses Program - Providing Waterway Classification and Criteria for Pesticides.

POLLUTION PREVENTION ASSESSMENT FOR THE PROPOSED "GREENS AT GALLOWAY" DEVELOPMENT, GALLOWAY TOWNSHIP, ATLANTIC COUNTY, NJ

I. INTRODUCTION

Plans for a proposed residential development, which would include a golf course in Galloway Township, Atlantic County were submitted to the Department for review. The property to be developed is approximately 371 acres in size; 123 acres would be residential, 91 acres would consist of an 18 hole golf course and the remaining acreage falls under the categories of wetlands, buffers, etc. The developers received a use variance from the Township to develop the golf course on land designated within the Township as open conservation.

II. OBJECTIVE

After the plans for the Greens at Galloway Development were received by the Department, the Land Use Regulation Program requested that the Standards and Systems Analysis Program (SSAP), within the Office of Regulatory Policy, review the proposed development plans. The objective of SSAP's review was to assess the water quality impact of a golf course development on the proposed site which is adjacent to a Category One waterway within the Edwin B. Forsythe National Wildlife Refuge (EFNWR).

III. STUDY AREA

The proposed 371 acre development is situated in the northeast corner of a 1,948 acre drainage basin. The Doughty Creek borders the northern border of the proposed development area and an unnamed creek borders the eastern side of the proposed development area. These two creeks, which are surrounded by wetlands, join together in the northeast corner of the proposed development and drain into Lily Lake which abuts and discharges directly into the Category One waterway in EFNWR. The distance between the juncture of the two creeks and the boundaries of the EFNWR is approximately one-third of a mile (Figure 1).

As per N.J.A.C. 7:9-4.15(c), the EFNWR has a surface water classification of FW2-NT/SE1 (Category 1). This classification designates bodies of water in which "No measurable change" is allowed (including calculable or predicted changes) to the existing water quality. The Doughty Creek and the unnamed creek will receive runoff and/or overflow waters from the proposed development and are located upstream of this Category 1 (C1) waterway. Therefore, the creek water quality must be maintained at a level which will not violate standards and will not cause any measurable (calculable or predicted) change to the C1 water quality downstream.

It was noted that an Oceanville Bog lies just beyond the 'wetlands buffer' to the proposed Galloways development. The wetlands classification for the bog ranges from a scrub/shrub mixture of conifer & deciduous trees on saturated soils to stands of white cedar in seasonally to semipermanent wet soils.

IV. SOIL and LAND USES

Soil information was obtained from the local Atlantic County Agricultural Extension Service and the Soil Survey of Atlantic County, New Jersey Soil Book. The major soil types composing the development are Sassafras, a sandy loam and Dower, a loamy sand. The soils coverage for the basin was obtained by digitizing the Ocean County SCS Soil Survey maps on the NJDEPE GIS (Geographic Information System). A summary soil series frequency table for the whole basin (Table 1.) was derived from this combined coverage. To obtain the area of each soil series in each subcatchment, a detailed frequency table (Table 2.) was consolidated. From this table it was found that of the nine soils present two soils represented approximately 61% of the total area. Sassafras soils represented 33% and Downer soils represented 28% of the total basin. Since these two soils have similar physical characteristics, rather than calculate a composite value for the various soil characteristics for each subcatchment, Sassafras was chosen as the typical soil for the entire basin for modeling purposes.

Pre-development, the 1,948 acre drainage basin contains 5 sub-basins which eventually drain into Lily Lake (Figure 1a.). Post development, due to the construction of residential and golf course which will cause a topographical alteration, the area will contain 19 new smaller sub-basins to control and direct water runoff (Figure 1b.). Eighteen of the newly created subbasins would contain portions of the golf course; only one sub-basin would be completely residential. Based on the drainage plans of the golf course, the proposed ten ponds are designed to primarily catch runoff from golf course which are composed of 10 sub-basins as shown in Figure 1. The remainder of the 19 sub-basins drain directly offsite into the two creeks flowing by the study area. In short, the 19 subbasins drain into either a pond or drain offsite into one of the two creeks draining into Lily Lake. Through regrouping into 'pond' and 'non-pond' catchments, the area represented by each land cover in each subbasin was determined and is shown in Table 3.

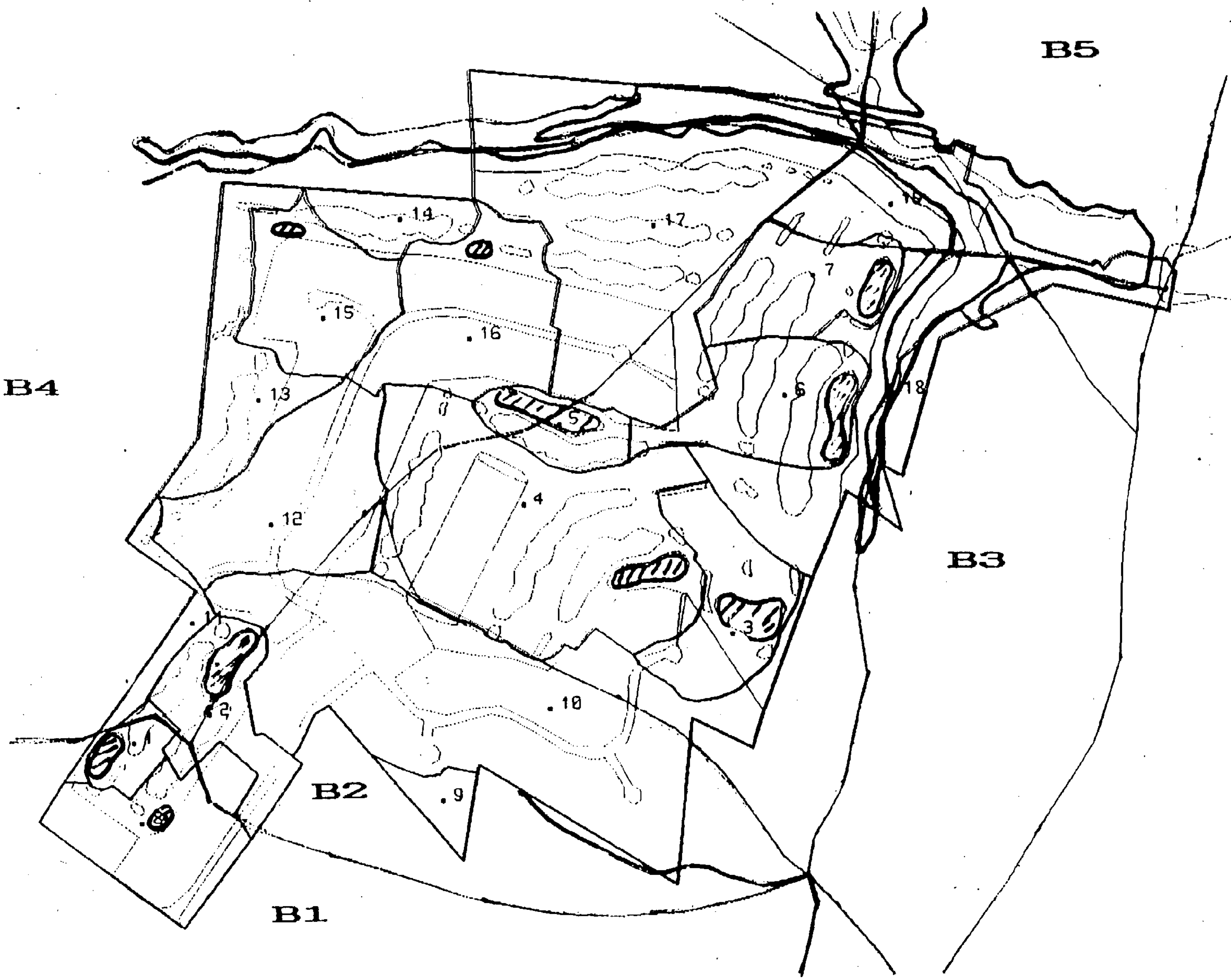


Figure 1. b. Proposed Site Plan for Greens at Galloways and development subcatchment delineation superimposed on the pre-development subbasin delineation.
(Note: numbers represent subcatchment number, green lines = pre-development subbasins, and blue lines = streams and ponds)

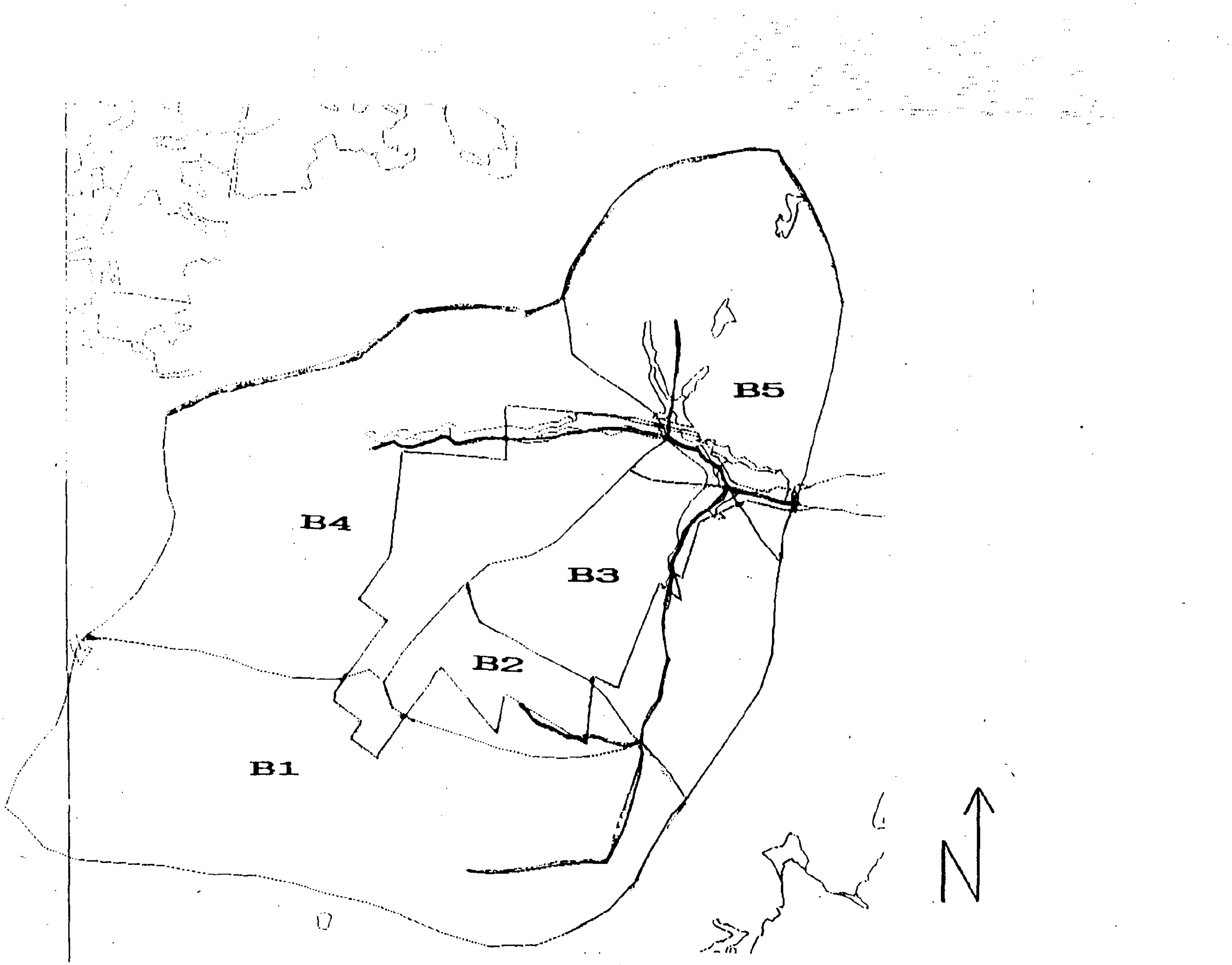


Figure 1. a. Pre- Greens at Galloways subbasin delineation and location of the proposed development.

Table 2. Soils & Land Use Data for Each Catchment Basin Above Lily Lake, Galloway Township, NJ (Total = 1948.97 Acres).

Sub-basin Name	L U Name	Soil Series	Acres of Soil for Each: Soil Series	Lnd Use Total	Subbas Total	Percentage of Subbasin: Soil/ Total	Soil/ Lnd Use	L U/ Total
B1	Glf	AmB	0.10			0.02	0.17	
		ArB	1.52			0.25	2.68	
		DoA	4.04			0.67	7.14	
		HaA	6.99			1.17	12.36	
		KmA	11.94			1.99	21.11	
		SaB	31.98	56.56		5.33	56.53	9.43
	Opn	ArB	76.85			12.82	16.76	
		DoA	147.25			24.55	32.12	
		HaA	92.69			15.46	20.21	
		KmA	60.81			10.14	13.26	
		SaA	10.82			1.80	2.36	
		SaB	70.09	458.50		11.69	15.29	76.46
	Res	ArB	22.24			3.71	26.27	
		DoA	24.59			4.10	29.06	
		HaA	13.29			2.22	15.71	
		KmA	6.87			1.14	8.11	
		SaB	17.64	84.63	599.69	2.94	20.85	14.11
B2	Opn	ArB	35.99			32.58	32.58	
		DoA	3.36			3.04	3.04	
		HaA	1.94			1.76	1.76	
		KmA	10.08			9.12	9.12	
		SaB	59.07	110.44	110.44	53.49	53.49	100.00
B3	Opn	Ac	10.69			3.88	4.04	
		ArB	11.89			4.31	4.49	
		DoA	148.20			53.76	56.02	
		HmA	11.95			4.33	4.52	
		KmA	0.01			0.00	0.00	
		MU	3.72			1.35	1.40	
		SaB	78.12	264.57		28.34	29.53	95.97
	Res	DoA	0.68			0.25	6.13	
		SaB	10.43	11.11	275.68	3.78	93.87	4.03

Table 1. Pre-Development Soil Association Acreage

Soil Series Symbol	Name	Seaview Golf Crse	Open	Res S/F	Total
		Area in Acres			
At	Atsion		41.26		41.26
AmB,ArB	Aura	1.62	270.55	43.69	315.85
DoA	Downer	4.04	472.12	72.00	548.16
EvB	Evesboro		2.53	2.89	5.41
HaA,HmA	Hammonton	6.99	227.84	27.27	262.10
KmA	Klej	11.94	72.62	11.62	96.18
MU	Muck		24.35	1.29	25.64
Po	Pocomoke		3.33	0.45	3.78
SaB	Sassafras	31.98	550.62	68.00	650.60
Total		56.56	1665.20	227.21	1948.97

Soil Series Symbol	Name	Open	Res S/F	Seaview Golf Crse	Total
		Percent Total Area of Basin			
At	Atsion		2.12		2.12
AmB,ArB	Aura	<0.01	13.88	2.24	16.21
DoA	Downer	0.21	24.22	3.69	28.13
EvB	Evesboro		0.13	0.15	0.28
HaA,HmA	Hammonton	0.36	11.69	1.40	13.45
KmA	Klej	0.61	3.73	0.60	4.93
MU	Muck		1.25	0.07	1.32
Po	Pocomoke		0.17	0.02	0.19
SaB	Sassafras	1.64	28.25	3.49	33.38

Table 3. Comparison of Pre- and Post- Greens at Galloway Golf Course Development Land Use Distribution

A. Study Area Land Use Distribution (Acres)

Subbasin	Open	Res	Turf	Ponded	Total All	Total Non-Ponded
1a	499.83	84.63	15.23	0.00	599.69	599.69
1b	478.55	85.61	15.23	20.31	599.69	579.38
2a	110.44	0.00	0.00	0.00	110.44	110.44
2b	43.43	12.25	44.91	9.85	110.44	100.59
3a	264.57	11.11	0.00	0.00	275.68	275.68
3b	157.46	22.72	1.70	93.80	275.68	181.88
4a	551.13	64.02	0.00	0.00	615.15	615.15
4b	458.80	126.57	15.46	14.32	615.15	600.83
5a	280.78	67.45	0.00	0.00	348.23	348.23
5b	279.62	68.24	0.37	0.00	348.23	348.23

B. Percent of Non-Pond Area

Subbasin	Open	Res	Turf
1a	83.35%	14.11%	2.54%
1b	82.60%	14.78%	2.63%
2a	100.00%	0.00%	0.00%
2b	43.17%	12.18%	44.65%
3a	95.97%	4.03%	0.00%
3b	86.57%	12.49%	0.94%
4a	89.59%	10.41%	0.00%
4b	76.36%	21.07%	2.57%
5a	80.63%	19.37%	0.00%
5b	80.30%	19.60%	0.11%

Subbasin 1 Turf acreage derived from the tees, fairways and greens distribution in the proposed Greens at Galloways:

	Galloways Golf Course Land Use Distribution Acres	Percent	Seaview G C Acres
F&T	50.24	25.87	14.63
G	2.04	1.05	0.59
RGH	141.92	73.08	41.33
Total	194.20		56.56

Note: Res = Residential Area (may include commercial),
Turf = Fairways, Tees and Greens, RGH = Rough
Open - All remaining area (includes golf course rough),
F&T = Fairways & Tees, G =Greens, a = pre-development,
b = post-development.

Table 2. Soils & Land Use Data for Each Catchment (cont.) (Total = 1948.97 Acres).

Sub-basin Name	L U Name	Soil Series	Acres of Soil for Each: Soil Series	Lnd Use Total	Subbas Total	Percentage of Subbasin: Soil/ Total	Soil/ Lnd Use	L U/ Total
B4	Opn	Ac	14.67			2.38	2.66	
		ArB	130.79			21.26	23.73	
		DoA	90.11			14.65	16.35	
		HaA	9.83			1.60	1.78	
		HmA	71.25			11.58	12.93	
		KmA	1.72			0.28	0.31	
		MU	7.32			1.19	1.33	
		SaA	83.25			13.53	15.11	
		SaB	142.17	551.13		23.11	25.80	89.59
	Res	ArB	21.45			3.49	33.51	
		DoA	26.08			4.24	40.73	
		HaA	0.08			0.01	0.12	
		HmA	1.91			0.31	2.99	
		KmA	4.75			0.77	7.42	
		SaA	9.75	64.02	615.15	1.59	15.23	10.41
B5	Opn	Ac	15.90			4.57	5.67	
		ArB	15.02			4.32	5.36	
		DoA	83.18			23.90	29.65	
		EvB	2.53			0.73	0.90	
		HaA	36.21			10.40	12.91	
		HmA	3.97			1.14	1.42	
		MU	13.32			3.83	4.75	
		Po	3.33			0.96	1.19	
		SaB	107.09	280.56		30.77	38.17	80.62
	Res	DoA	20.66			5.94	30.62	
		EvB	2.89			0.83	4.28	
		HaA	11.99			3.45	17.78	
		MU	1.29			0.37	1.91	
		Po	0.45			0.13	0.67	
		SaB	30.18	67.45	348.01	8.67	44.75	19.38

Note:

Glf = Seaview Country Club & Golf Course
Opn = Open space (i.e. not residential or golf course)
Res = Primarily single-family residential area; may include commercial/industrial development.

V.1.1 Database and input information

A. Pesticides

The following list of pesticides to be used at the golf course was submitted by the developers:

HERBICIDES	FUNGICIDES	INSECTICIDES
MCPP	Benomyl	Chlorpyrifos
Bensulide	Iprodione	
Oxadiazon	Triadimefon	
	Maneb	
	Anilazine	
	Metalaxyl	
	Thiram	

In this study, five of the above pesticides were selected for simulation due to the availability of the data. The five pesticides run through PRZM were: Chlorpyrifos, Maneb, Bensulide, Benomyl and Metalaxyl. Application rates were supplied by the permittee. Fungicides are to be applied monthly from May through September. Insecticides are to be applied as needed with a one time application to the fairways. Herbicides are to be applied twice a year.

Pesticide application dosages used in the model were the percent active ingredient present. The simulation duration for the pesticides were 3 consecutive years with an exception of Chlorpyrifos which was simulated with various design storm events. In summary, the scenarios for pesticides are:

a. Chlorpyrifos - Chlorpyrifos is an insecticide which is proposed to be used on the greens and fairways of the golf course. The scenarios conducted for Chlorpyrifos were one application each at the rates of 1 lb/acre, 4 lb/acre and 8 lb/acre immediately prior to design storm events.

b. BENOMYL - Benomyl is a fungicide which is to be used at the golf course on greens, tees and fairways. Benomyl is to be applied once per month from May through September for three consecutive years. As per the technical data sheet, Benomyl is toxic to fish. Benomyl is not to be applied where runoff is likely to occur. The 96 hour LC50 for rainbow trout is 0.41 ppm.

c. BENSULIDE - Bensulide is an herbicide which is to be used at the golf course on greens, tees and fairways. Bensulide is to be applied two times per year for three years. As per the Material Safety Data Sheet untreated

V. MATERIAL and METHODS

In order to evaluate the quality and quantity of the runoff water from the proposed development site entering the Doughty Creek which eventually flows into the EFNWF, two computer models, STORM (Storage, Treatment, Overflow, Runoff Model) and PRZM (Pesticide Root Zone Model), and one desktop groundwater model were selected to assess the pesticides and nutrients impact on receiving water via surface runoff and ground water seepage.

In order to ensure pollution prevention to the downstream Category One water, the simulated scenarios were conducted with conservative assumptions. For instance, a pesticide or nutrient application followed by a severe rainfall was a scenario used for analysis.

Based on consultation with the USGS, the MA7CD10 flow at the confluence of the Doughty Creek and the unnamed creek is 1.1 cfs which was used as a basis for instream impact analysis.

V.1 PRZM

PRZM, an EPA model, is primarily used to determine pesticide chemical movement and hydrology in the soil. The pesticide runoff flux (in grams per cm^2 of soil) and water runoff (in cm) are the simulation outputs from PRZM. From these two pieces of information and proposed acreage of greens, tees and fairways within a particular subbasin to which the pesticide would be applied, the amount of pesticide and volume of water the ppb is then calculated.

The information required for producing pesticide runoff flux includes: pesticide soil decay rate, pesticide application rates, pesticide foliar washoff rates, the formulation of pesticide applied, etc. The data required for computing the runoff are rainfall data, soil data, and crop data of the site. The resources of required input data used for this simulation are presented in Appendix B. A more detailed discussion of the inputs follows.

The rainfall data used for simulation of the Chlorpyrifos are 1-year, 2-year, 5-year, 10-year, 25 year, 50-year and 100-year design 24 hour type III storms.

C. PRZM DATA INPUT

(1). Control Parameters

Time Series	daily
Number of Chemicals	5
Number of Compartments	50

(2). Hydrology Parameters

Pan Factor (estimates ET)	.77
Min. depth to extract evap.	17.5 CM
Ave. dly hrs of daylight/mnth	10.00 10.50 11.80 13.10 14.20 14.70 14.4 13.90 12.20 11.00 9.80 9.20
Maximum interception storage of crop	.30
Maximum active root depth of crop	90 cm
Maximum Areal Coverage of crop	85%
Runoff Curve Number (CN)	61

(3). Pesticide Parameters

Pesticide	Washoff precp.	Foliar decay rate	Plant uptake rate	Decay rate
Bensulide	n/a	n/a	.069	.012
Metalaxyl	.07	.70	.010	.027
Maneb	.28	.10	.280	.023
Benomyl	.11	.25	.660	.069
Chlorpyrifos	.288	.10	.781	.023

(4). Pesticide names and applications:

Bensulide (Herbicide):

Greens -	2 applications/year @ 14 kg/ha/appl
Tees & Fairways -	2 applications/year @ 3.34 kg/ha/appl

Benomyl (Fungicide):

Greens, Tees & Fairways -	5 applications/year @ 1.590 kg/ha/appl

Maneb (Fungicide):

Greens -	5 applications/year @ 9.7 kg/ha/appl
Tees & Fairways -	5 applications/year @ 4.48 kg/ha/appl

effluent should not be discharged where it will drain into lakes, streams, or ponds. Bensulide is not to be applied where runoff is to occur.

d. **METALAXYL** - Metalaxyl is a fungicide which is to be used at the golf course on tees and fairways. Metalaxyl is to be applied once a month from May through September for three consecutive years.

e. **MANEB** - Maneb is a fungicide which is to be applied to the golf course on the greens, tees and fairways. The scenario used for simulation of the Maneb is same as that for Metalaxyl.

B. Criteria or limits of Pesticides

Although the regulatory guideline for Category One waters is "no measurable change", literature was searched and the following criteria or levels were found:

(1). Environmental Protection Agency's 304(a) criteria:

		Acute	Chronic
Chlorpyrifos:	Freshwater	0.083 ppb	0.041 ppb
	Saltwater	0.011 ppb	0.0056 ppb

(2). Best Available Scientific Information Criteria (BASIC) developed by the New Jersey Department of Environmental Protection and Energy based on information obtained from EPA's Integrated Risk Information System (IRIS):

Benomyl	- 350 ppb
Metalaxyl	- 420 ppb

(3). Aquatic LC50 values / Application factor of 0.01

Aquatic LC50 values		Application factor of 0.01	
Bensulide	- 379 ppb	Bensulide	- 3.79 ppb
Maneb	- 110 ppb	Maneb	- 1.10 ppb
Benomyl	- 5.6 ppb	Benomyl	- 0.056 ppb

The aquatic LC50s were obtained from Aquatic Toxicity Information Retrieval Data Base (ACQUIRE) multiplied by an application factor of 0.01 to provide a degree of protection for sensitive aquatic organisms as suggested in Quality Criteria for Water (in section of "the Philosophy of Quality Criteria", USEPA, 1976).

(8). Meteorological File

Rainfall rates for the years 1984 through 1986 were taken from the NOAA weather data. Figure 2 illustrates the rainfall records for 1984 - 1986.

The minimum rainfall size required for generating a runoff is assumed to be 2.5 cm. This is due to the high permeability of the soil and low impervious area of the study area. Factors affecting the quantity of pesticide in the runoff are: solubility of the pesticide, pesticide decay rate, pesticide foliar washoff fraction, number and amount of applications of pesticides and formulation of the applied pesticide.

V.2 Storage, Treatment, Overflow, Runoff Model "STORM"

A modified version of the HEC STORM program, which was used for assessment of water quality impact from the Smithville Development Study (1982, Najarian), was used to simulate basin wide nutrient quantity and quality of runoff from urban and nonurban watersheds. The model generates tabulated pollutograph data (e.g. flow, concentration, loading rate, etc.). Six basic water quality parameters can be simulated (suspended solids, settleable solids, biochemical oxygen demand, total nitrogen, orthophosphate, and total coliform).

The applicant proposes to "use soluble fertilizers and pulverized lime ... immediately before forecasted rainfall or irrigation..." (Edstrom, 1990, p. 16). The practice of applying the fertilizer " immediately before" a rainfall or irrigation, as stated, will tremendously increase the potential for impact due to storm runoff. Therefore, more nutrients would be carried to the bog during wet weather period of time. Based on pollution prevention approach, the assessment of nutrient impact to the receiving water was conducted using scenarios that storm events immediately follow fertilizer applications.

The 1-yr, 2-yr, 5-yr and 25-yr design storm precipitation distributions were utilized in this analysis of the proposed Galloways development.

Metalaxyl (Fungicide):

	Tees & Fairways -	5 applications/year @ .38 kg/ha/appl
Chlorpyrifos (Insecticide)	-	1 application/year @ 0.56, 2.24 & or 4.48 kg/ha/appl

(5). Soil Parameters

Major soil type	Sassafras
Total Depth of Core (cm)	150
Number of Horizons	3

Horizon	Thickness (cm)	Bulk density (g/cm^3)	Field Cap. (cm^3/cm^3)	Wilting pt. (cm^3/cm^3)
1	45	1.4	.284	.124
2	50.5	1.4	.394	.174
3	55.5	1.5	.184	.064

(6). K_d RATE (Decay Rate, 1/day, in Different Horizons)

	HRZN 1	HRZN 2	HRZN 3
Bensulide	58.005	11.601	5.8
Metalaxyl	0.093	0.019	0.009
Maneb	5.8	1.16	0.58
Benomyl	12.18	2.4	1.2
Chlorpyrifos	35.2	7.04	3.5

(7). Golf Course Land Use Distribution (acres)

PONDS	GREENS	TEES	FAIRWAYS
1	0.00	0.13	0.81
2	0.16	0.17	2.76
3	0.24	0.47	0.00
4	0.34	1.06	15.41
5	0.08	0.00	2.58
6	0.19	0.13	5.27
7	0.05	0.24	3.37
8	0.09	0.08	0.57
9	0.00	0.04	0.25
10	0.00	0.19	0.02
NON-PONDED	0.90	1.88	14.76

V.2.1. Input Data for STORM model

A. General and Design Storm Data

The coefficients used for nutrient simulation using STORM model were adopted from previous runoff studies such as Upper Millstone River Runoff Study (NJDEPE, 1991) and the Historic Smithville Towne development studies (Najarian, 1982). The modifications made were to reflect the acreage of the basins, land use distribution (percent), rainfall distribution and nutrient application rate. Design storm distributions for the 1-yr, 2-yr, 5-yr and 25-yr event were used as the rainfall data for assessment of nutrient impact during wet weather time.

B. Pre-development Simulation

Based on the 1989 USGS Oceanville topographic quadrangle stream delineations and the proposed Greens at Galloway site plan, the Upper Doughty Creek Basin was divided into five subbasins. Each of these subbasins are defined by the hydrologic divide for that stream segment.

The land use distribution was determined by digitizing the approximate outline of the existing residences and the Seaview Golf Club. Commercial properties were included in the residential area. The remaining area was designated as Open. Due to insufficient data of the Seaview golf course location within Basin 1, the land use distribution of the Seaview golf course was assumed to be similar to that of the proposed Greens at Galloway Golf Course (Table 3). In other words, in this study the Seaview golf course area was divided up into tees, fairways, greens and rough by the percent of each of these areas in the Galloways golf course. In the pre-development phase, the Seaview golf course is the major area on which the fertilizer was applied.

C. Post-development Simulation

The land use coverage was modified by digitizing the Greens at Galloway site plan provided by the applicant. The land uses delineated at the proposed development were Fairways, Greens, Tees, Rough, Residential and Wetlands Buffer. After the Galloway golf course development, the fertilizer application area will consequently be increased. The land use of post-development of the Galloway golf course was described in previous sections and was used for assessment of nutrient impact.

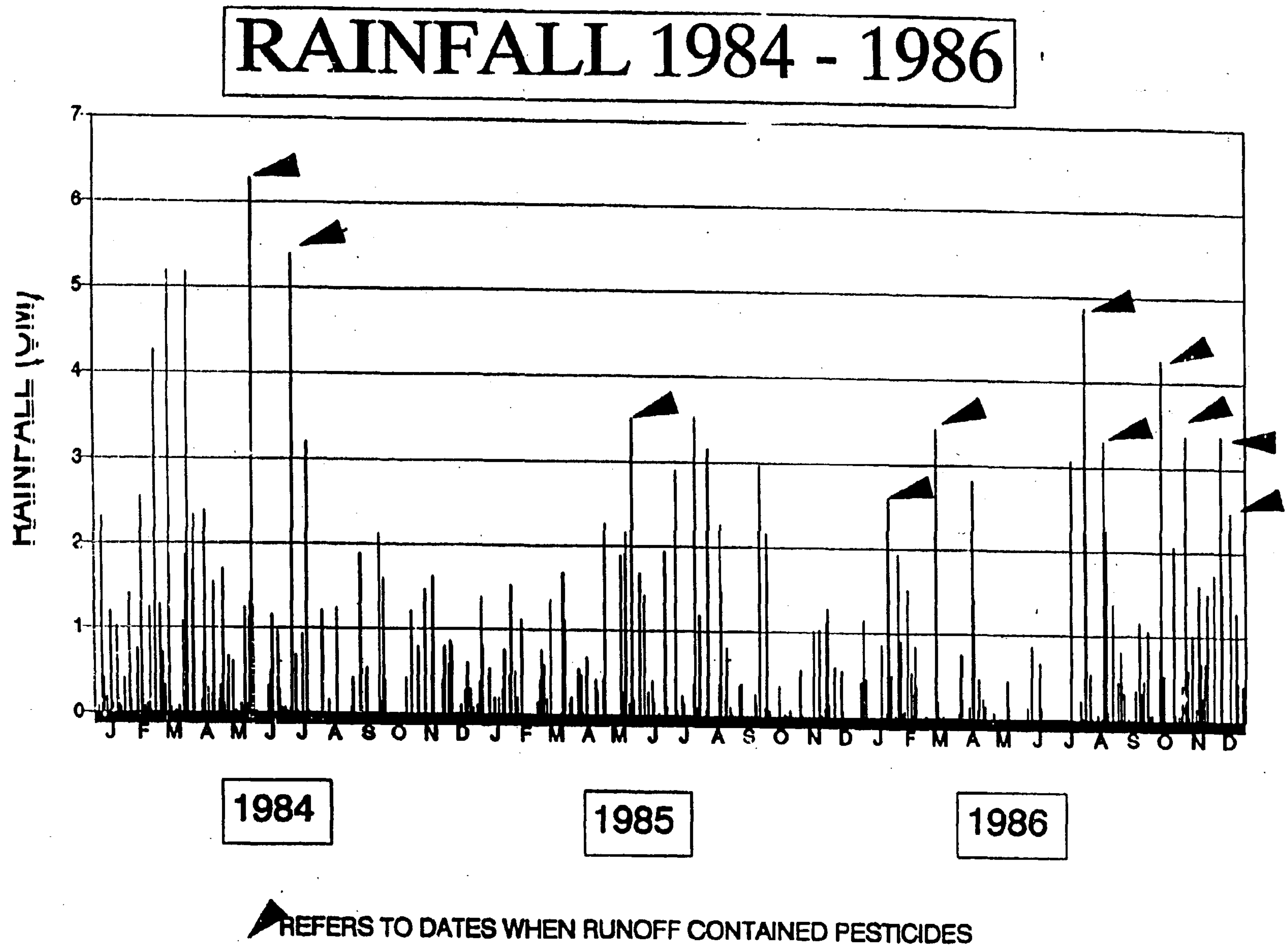


Figure 2. Rainfall Size for 1984 - 1986

transport equation governing advection, dispersion, first-order decay and linear, equilibrium adsorption in two dimensions in the aquifer for the above cases is:

$$R_d \frac{\partial c}{\partial t} + v_x \frac{\partial c}{\partial x} = D_x \frac{\partial^2 c}{\partial x^2} + D_y \frac{\partial^2 c}{\partial y^2} - kR_d c + m' \frac{\delta(x)\delta(y)\delta(t)}{p}$$

The last term on the right side of Equation represents the instantaneous discharge of mass at initial location. The m' in the equation is the strength of the discharge obtained by a formula that the mass of contaminants in injected divided by the thickness of the aquifer. The solution to the equation can be found by means of the integral transform or Laplace transform techniques:

$$c(x,y,t) = \frac{c_0 Q'}{b4\pi pt(D_x D_y)^{\frac{1}{2}}} \exp\left(-kt - \frac{(xR_d - v_x t)^2}{4D_x tR_d} - \frac{(yR_d)^2}{4D_y tR_d}\right)$$

where

- c_0 = initial concentration of contaminant being discharged (mg/l)
- Q = volume of contaminant being discharged (m^3)
- b = saturated thickness of aquifer (m)
- p = effective porosity (decimal percent, unitless)
- t = time (days)
- Dx = dispersion coefficients in x directions (m^2/day)
- Dy = dispersion coefficients in y directions (m^2/day)
- v_x = seepage velocity of the regional flow in the x direction (m/d)
- x,y = location of point of interest (m), where the source is located at x=0, y=0
- k = first-order decay constant of the contaminant in the aquifer
- R_d = retardation coefficient for linear, equilibrium adsorption

The seepage velocity, v_x, is defined as:

v_x = $(k_h/p)*(dH/dl)$........................(c)

where

- k_h = hydraulic conductivity (ft/day)
- dH = hydraulic head change (ft)
- dl = distance between two interested points (ft)

The retardation factor, R_d, is defined as:

D. Nutrient Application Rates

The model assumes that nutrients are applied evenly over an entire subbasin. In the case of a golf course, nutrients are not applied evenly over the entire golf course area. The application rates proposed by the applicant (Keenan, 1991) were utilized. Since phosphorus is only to be applied "as needed", the emphasis was only on nitrogen. The amount of nitrogen to be applied is as follows: on the tees and fairways, 150 pounds per acre per year for three applictions; on greens, 6 pounds per acre per year for three applications; no nitrogen is to be applied to the rough area. The application rate for nitrogen in each subbasin was assumed to be one third of proposed total application rate and was calculated as follows:

Fairways & Tees:

F&T_Acres * 50 lb/Ac/day = F&T_Amt

Greens:

G_Acres * 2 lb/Ac/day = G_Amt

Total:

T_Area = F&T_Acres + G_Acres
T_N_Amt = F&T_Amt + G_Amt

Application Rate:

T_N_Amt / T_Area

The application rate value was then utilized in the STORM input file as the loading rate for nitrogen.

V.3 Assessment of Impact via Ground Water Media to the Receiving Water

As stated in previous section, the soil type in the study area is mostly sandy loam with low organic content. The mobility of pesticides in this kind of soil is considered to be high duc to the fact that soil has higher water conductivity and lower capacity for retaining organic compounds. Therefore, the pollution to the receiving water via ground water route should be assessed.

In this assessment, the waste is considered to have been instantaneously discharged at a point. Such an instantaneous discharge is also called a slug source. This approach has been used for assessing the pollutant impacts

Since the information regarding the subsurface is insufficient, assumptions were made in order to perform assessment including bulk density, hydraulic conductivities, hydraulic gradient, and saturated flow thickness. For assessment of the impact via groundwater transport, not all the ponds and pesticides were used for analysis but only Pond 7 and Metalaxyl were selected. The rationale of this selection is that Pond 7 is one of the ponds, which is located near the receiving water, and is of most concern. Metalaxyl, obtained from EPA Environmental Fate data base, has a lowest Koc (~20) among selected pesticides and is expected to give a lower retardation factor and relatively higher mobility.

VI. RESULTS

VI.1. Pesticides Simulation

The pesticide impact to the receiving water was assessed using various pieces of information including rainfall, pesticide application rate, soil information, receiving water flow and pesticide chemistry and fate information which are discussed in section on data input.

The results for Benomyl, Metalaxyl, Bensulide, and Maneb are illustrated in Tables 4 to 8. Tables 9 to 11 present the Chloropyrifos concentrations in the ponds, stream and runoff waters caused by different designed storm events.

The results indicate the following: Benomyl exceeds the aquatic protection level of 0.056 ug/l for runoff levels within each of the 10 subbasins draining into the ponds and the instream concentration originating from the non-ponded golf course areas. Maneb exceeds the aquatic protection level of 1.10 ug/l for runoff levels within each of the 10 subbasins draining into the ponds and the instream concentration originating from the non-ponded golf course areas. Bensulide exceeds the aquatic protection level of 3.79 ug/l for runoff levels within subbasins 1 through 8 draining into these respective ponds. Levels for Bensulide did not exceed the aquatic protection level for the instream concentration although a predicted amount of this pesticide will enter the streams. For Metalaxyl an aquatic protection level is unknown, although a predicted amount of this pesticide will enter the streams and the ponds from the subbasins. Chlorpyrifos exceeds EPA's 304(a) criteria for both instream concentrations and for runoff levels entering each pond. The results of pesticide concentrations in the ponds and instream water are shown in Appendix A.

$$R_d = 1 + (K_d * \text{bulk desity}/p) \ldots\ldots\ldots\ldots (d)$$

where

K_d = distribution coefficient (ml/g), a ratio of concentration of pollutant sorbed on soil to that in solution.

and

$$K_d = K_p = K_{oc} * X_{oc} \ldots\ldots\ldots\ldots (e)$$

$$K_{oc} = 0.937 \log K_{ow} - 0.006 \ldots\ldots\ldots\ldots (f)$$

where

K_p = Partition Coefficient
K_{ow} = Octanol-water partition coefficient
X_{oc} = Mass fraction of organic carbon in sediment
K_{oc} = Partition Coefficient expressed on an organic carbon basis

The maximum concentration at any specified location occurs at time t_{max}. This time is computed as:

$$t_{max} = (- B + (B^2-4AC)^{1/2}) / (2A) \ldots\ldots\ldots\ldots (g)$$

where

$$A = (k4D_xD_yR_d + v_x{}^2D_y) \ldots\ldots\ldots\ldots (h)$$

$$B = (4D_xD_yR_d) \ldots\ldots\ldots\ldots (i)$$

$$C = - (x^2 R_d{}^2 D_y + y^2 R_d{}^2 D_x) \ldots\ldots\ldots\ldots (j)$$

V 3.1. Input data for Slug Source Ground Water Model

Bulk density = 1.5 (assumed)
K_{oc} of Matalaxyl = 20
Volume of Pond 6 = 4757 m^3 (after 100-year storm)
Volume of Pond 7 = 4032 m^3 (after 100-year storm)
Area of Pond 7 = 1.8 acre (78408 ft^2)
K_h (horizontal) = 133 ft/day (assumed to be similar to that of Spring Mill Drive site, Galloway township, NJ as reported by NJDEPE, 1992)
Permeability = 8 ft/day (from USDA SCS for Dower soil)
dH/dl = 0.0037 ft/ft (assumed to be similar to Spring Mill Drive site, Galloway township, NJ as reported by NJDEPE, 1992)
p (porosity) = 0.20 (assumed)
Saturated flow thickness at Pond 6 = 4 ft (from USDA SCS)
Saturated flow thickness at Pond 7 = 4 ft (assumed)
X_{oc} = 0.5% (use Downer soil)
x6, distance from Pond 6 to river = 300 ft
x7, distance from pond 7 to river = 350 ft

TABLE 4 . PREDICTED CONCENTRATION OF PESTICIDE IN DOUGHTY CREEK AND UNNAMED STREAM ORIGINATING FROM RUNOFF FROM NON-POND AREAS OF GOLF COURSE (UG/L)

PESTICIDE	APPL.RATE	MINIMUM	MAX.	AVG.	S.D.
BENOMYL	22 OZ/ACRE	1.47E-06	1.1	0.22	0.40
METALAXYL	22 OZ/ACRE	2.8E-09	3.8	0.67	1.42
BENSULIDE	12.5 LB/ACRE (GREENS) & 3 LB/ACRE (TEES & FRWYS)	.0009	0.84	0.30	0.28
MANEB	4 OZ/1000 FT^2 (GREENS) & 88 OZ/ACRE (TEES&FRWYS)	.00047	4.7	1.18	1.52

TABLE 5. PREDICTED CONCENTRATION OF BENOMYL IN RUNOFF FLOWING INTO PONDS 1 - 10 WITHIN EACH SUBBASIN (UG/L) APPLICATION RATE: 22 OZ/ACRE

POND	MINIMUM	MAXIMUM	AVERAGE	STAN.DEV.
1	5.21E-05	42.7	08.97	14.07
2	5.73E-05	46.9	09.85	15.45
3	1.07E-05	08.8	01.84	02.89
4	7.83E-05	64.1	13.48	21.14
5	8.57E-05	70.2	14.75	23.14
6	7.95E-05	65.1	13.67	21.45
7	5.64E-05	46.2	9.71	15.23
8	1.23E-05	10.0	2.11	3.31
9	0.000125	3.9	0.83	1.31
10	3.48E-06	2.8	0.59	0.93

TABLE 6. PREDICTED CONCENTRATION OF METALAXYL IN RUNOFF FLOWING INTO PONDS 1- 10 WITHIN EACH SUBBASIN (UG/L) - APPLICATION RATE 22 OZ/ACRE

POND	MINIMUM	MAXIMUM	AVG.	STAN. DEV.
1	4.58E-06	151.5	25.0	52.0
2	4.77E-06	157.8	26.0	54.2
3	6.25E-07	20.6	3.4	7.0
4	6.75E-06	223.0	36.8	76.6
5	7.31E-06	241.7	39.9	83.0
6	4.51E-06	149.2	24.6	51.2
7	5.33E-06	176.2	29.0	60.5
8	9.48E-07	31.3	5.1	10.7
9	4.28E-07	14.1	2.3	4.8
10	3.06E-07	10.1	1.6	3.4

TABLE 7. PREDICTED CONCENTRATION OF BENSULIDE IN RUNOFF FLOWING INTO PONDS 1 - 10 - GREENS APPLICATION RATE 12.5 A.I./ACRE; FAIRWAYS AND TEES APPLICATION RATE 3 LB A.I./ACRE

POND	MINIMUM	MAXIMUM	AVERAGE	STAN. DEV
1	3.12	20.0	10.2	5.1
2	3.99	25.6	13.0	5.6
3	1.33	8.5	4.3	1.4
4	19.6	126.3	64.4	38.5
5	21.0	135.0	68.9	42.2
6	13.0	83.8	42.7	25.9
7	15.3	98.4	50.2	30.9
8	2.70	14.0	9.1	5.3
9	0.29	1.8	0.9	0.4
10	0.21	1.3	0.7	1.4

TABLE 8. PREDICTED CONCENTRATION OF MANEB IN RUNOFF FLOWING INTO PONDS 1 - 10 (in UG/L) - GREENS APPLICATION RATE 4 OZ/1000 FT^2; FAIRWAYS AND TEES APPLICATION RATE 88 OZ/ACRE

POND	MINIMUM	MAXIMUM	AVERAGE	STAN. DEV.
1	5.2	167.1	47.0	53.7
2	0.6	194.6	54.8	44.7
3	0.15	47.9	13.5	7.54
4	0.80	165.8	72.3	64.2
5	3.71	284.5	80.1	69.2
6	0.57	183.2	51.6	42.3
7	0.63	200.1	56.3	50.9
8	0.14	44.9	12.6	8.72
9	0.20	15.61	4.3	5.01
10	0.03	7.20	3.1	3.58

TABLE 9. PREDICTED CONCENTRATION OF CHLORPYRIFOS ENTERING LILY LAKE FROM DOUGHTY CREEK AND UNNAMED STREAM ORIGINATING FROM NON-PONDED AREAS OF GOLF COURSE (PESTICIDE WAS APPLIED TO GREEN (ONLY)

STORM EVENT & APPLICATION RATE	PPB	STORM EVENT & APPLICATION RATE	PPB
1 YR/1 LB APPL.	0.008	10 YR/1 LB APPL.	0.011
1 YR/4 LB APPL.	0.032	10 YR/4 LB APPL.	0.044
1 YR/8 LB APPL.	0.064	10 YR/8 LB APPL.	0.088
2 YR/1 LB APPL.	0.009	25 YR/1 LB APPL.	0.011
2 YR/4 LB APPL.	0.037	25 YR/4 LB APPL.	0.044
2 YR/8 LB APPL.	0.074	25 YR/8 LB APPL.	0.089
5 YR/1 LB APPL.	0.010	50 YR/1 LB APPL.	0.011
5 YR/4 LB APPL.	0.040	50 YR/4 LB APPL.	0.046
5 YR/8 LB APPL.	0.081	50 YR/8 LB APPL.	0.093
		100 YR/1 LB APPL	0.011
		100 YR/4 LB APPL	0.047
		100 YR/8 LB APPL	0.095

TABLE 10. PREDICTED CONCENTRATION OF CHLORPYRIFOS ENTERING LILY LAKE FROM DOUGHTY CREEK AND UNNAMED STREAM ORIGINATING FROM RUNOFF FROM NONPONDED AREA OF GOLFCOURSE (PESTICIDE APPLIED TO FAIRWAYS ONLY)

STORM EVENT & APPLICATION RATE	PPB	STORM EVENT & APPLICATION RATE	PPB
1 YR/1 LB APPL.	0.131	10 YR/1 LB APPL.	0.181
1 YR/4 LB APPL.	0.524	10 YR/4 LB APPL.	0.726
1 YR/8 LB APPL.	1.049	10 YR/8 LB APPL.	1.453
2 YR/1 LB APPL.	0.152	25 YR/1 LB APPL.	0.184
2 YR/4 LB APPL.	0.610	25 YR/4 LB APPL.	0.736
2 YR/8 LB APPL.	1.221	25 YR/8 LB APPL.	1.472
5 YR/1 LB APPL.	0.167	50 YR/1 LB APPL.	0.191
5 YR/4 LB APPL.	0.669	50 YR/4 LB APPL.	0.765
5 YR/8 LB APPL.	1.339	50 YR/8 LB APPL.	1.531
		100 YR/1 LB APPL.	0.195
		100 YR/4 LB APPL.	0.781
		100 YR/8 LB APPL.	1.562

VI.2 Nutrient Simulation Results

As stated, in order to simulate the water quality for this area, the 1-yr, 2-yr, 5-yr and 25-yr type III design storm distributions were utilized. The results obtained from running the STORM program are the hourly concentration and loading for each subbasin.

Table 12 presents the results of nitrogen loading from each basin as to storm events. Figures 3 to 6 illustrate the hourly loadings of each basin under various designed storm events. It was noted that the golf course areas produce a high loading of nitrogen in the runoff in both the pre-Galloways and post-Galloways simulations (Figure 3). Nutrient loadings in all basins will increase after development of the Galloways golf course based on the simulation. (Note the scale change from pre-Galloways to post-Galloways.) The conversion of 'open' space to 'turf' tends to cause a dramatic increase in the nitrogen loading to the upper Doughty Creek and the Oceanville Bog.

Table 12. Nitrogen Loading From Each Basin (lb/basin/storm)

Pre-Development				
	1 YR	2 YR	5 YR	25 YR
B1	4.55	5.08	5.65	5.99
B2	0	0	0.02	0.02
B3	0.02	0.02	0.02	0.03
B4	0.06	0.06	0.07	0.1
B5	0.06	0.06	0.07	0.07
Post-Development				
	1 YR	2 YR	5 YR	25 YR
B1	4.71	5.23	5.77	6.09
B2	0.33	0.37	0.4	0.41
B3	0.47	0.5	0.55	0.62
B4	5.33	5.87	6.37	6.67
B5	0.16	0.19	0.22	0.25

TABLE 11. PREDICTED CONCENTRATION OF CHLORPYRIFOS IN RUNOFF FLOWING INTO PONDS FROM EACH SUBBASIN (UG/L)

	100 YEAR DESIGN STORM			25 YEAR DESIGN STORM		
POND #	1 LB/ ACRE	4 LB/ ACRE	8 LB/ ACRE	1 LB/ ACRE	4 LB/ ACRE	8 LB/ ACRE
1	4.31	17.24	34.48	4.08	16.32	32.64
2	4.90	19.63	39.26	4.64	18.58	37.16
3	0.00	0.00	0.00	0.00	0.00	0.00
4	6.88	27.55	55.11	6.52	26.08	52.17
5	8.01	32.05	64.10	7.58	30.33	60.67
6	7.19	28.79	57.58	6.81	27.25	54.50
7	5.43	21.72	43.44	5.14	20.56	41.12
8	0.90	3.62	7.25	0.85	3.43	6.86
9	0.34	1.37	2.75	0.32	1.30	2.60
10	0.02	0.08	0.16	0.01	0.07	0.15

	10 YEAR DESIGN STORM			5 YEAR DESIGN STORM		
POND #	1 LB/ ACRE	4 LB/ ACRE	8 LB/ ACRE	1 LB/ ACRE	4 LB/ ACRE	8LB/ ACRE
1	16.12	32.24	40.30	3.74	14.98	29.99
2	18.35	36.71	45.89	4.26	17.05	34.09
3	0.00	0.00	0.00	0.00	0.00	0.00
4	25.76	51.53	64.4	5.98	23.94	47.86
5	29.96	59.93	74.92	6.95	27.84	55.66
6	26.92	53.25	67.30	6.25	25.01	50.00
7	20.31	0.62	50.77	4.71	18.87	37.72
8	3.39	6.78	8.47	0.78	3.15	6.30
9	1.28	2.57	3.21	0.29	1.19	2.39
10	0.07	0.15	0.19	0.01	0.07	0.14

1 YEAR DESIGN STORM

POND #	1 LB/ ACRE	4 LB/ ACRE	8 LB/ ACRE
1	3.11	12.45	24.90
2	3.54	14.17	28.35
3	0.00	0.00	0.00
4	4.97	19.90	39.80
5	5.78	23.14	46.29
6	5.19	20.79	41.58
7	3.92	15.68	31.37
8	0.65	2.61	5.23
9	0.24	0.99	1.98
10	0.01	0.05	0.11

Pre-Development

Post-Development

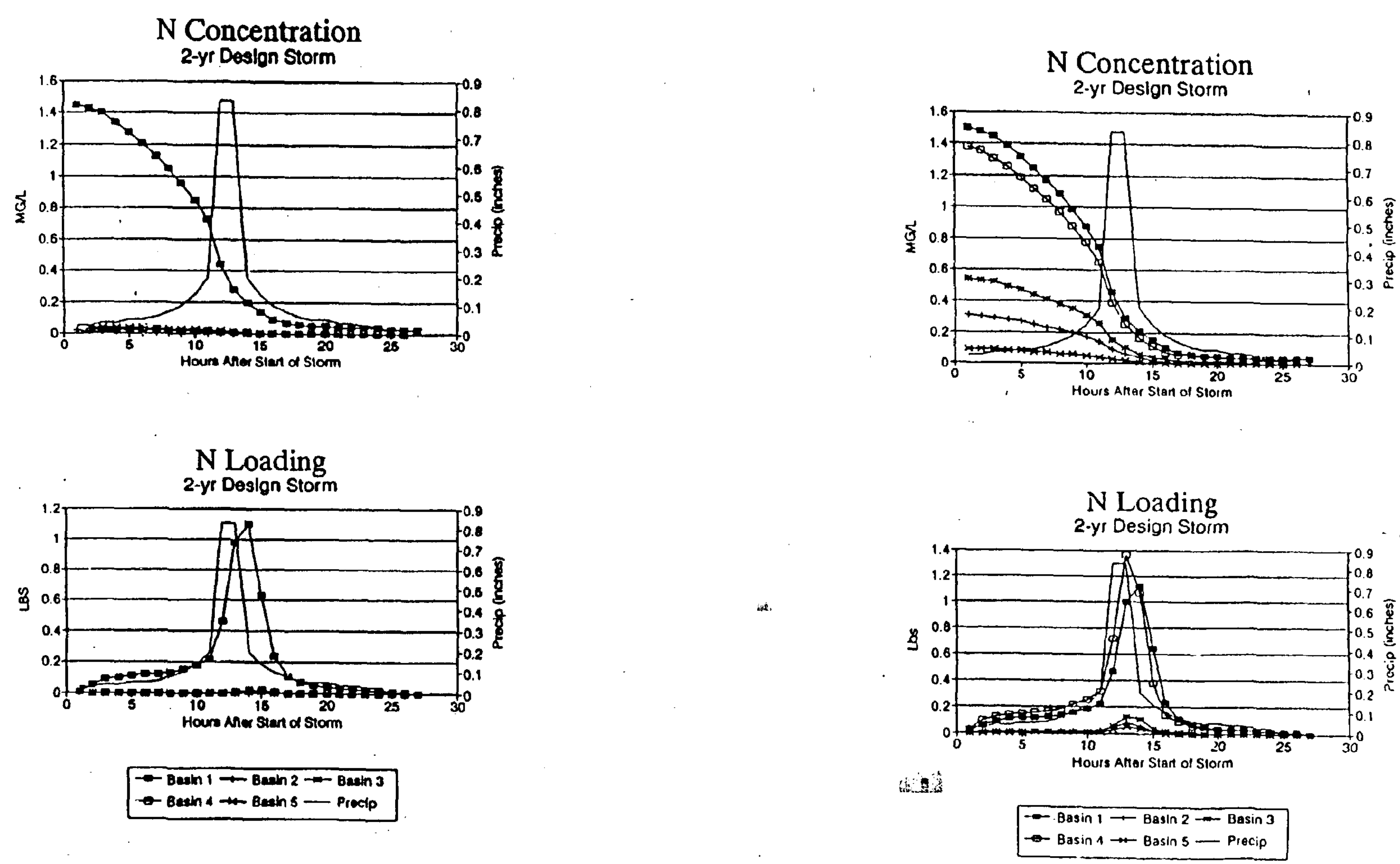


Figure 4. Pre- and Post- Greens at Galloways development nitrogen concentration and loading for the 2-year design storm event.

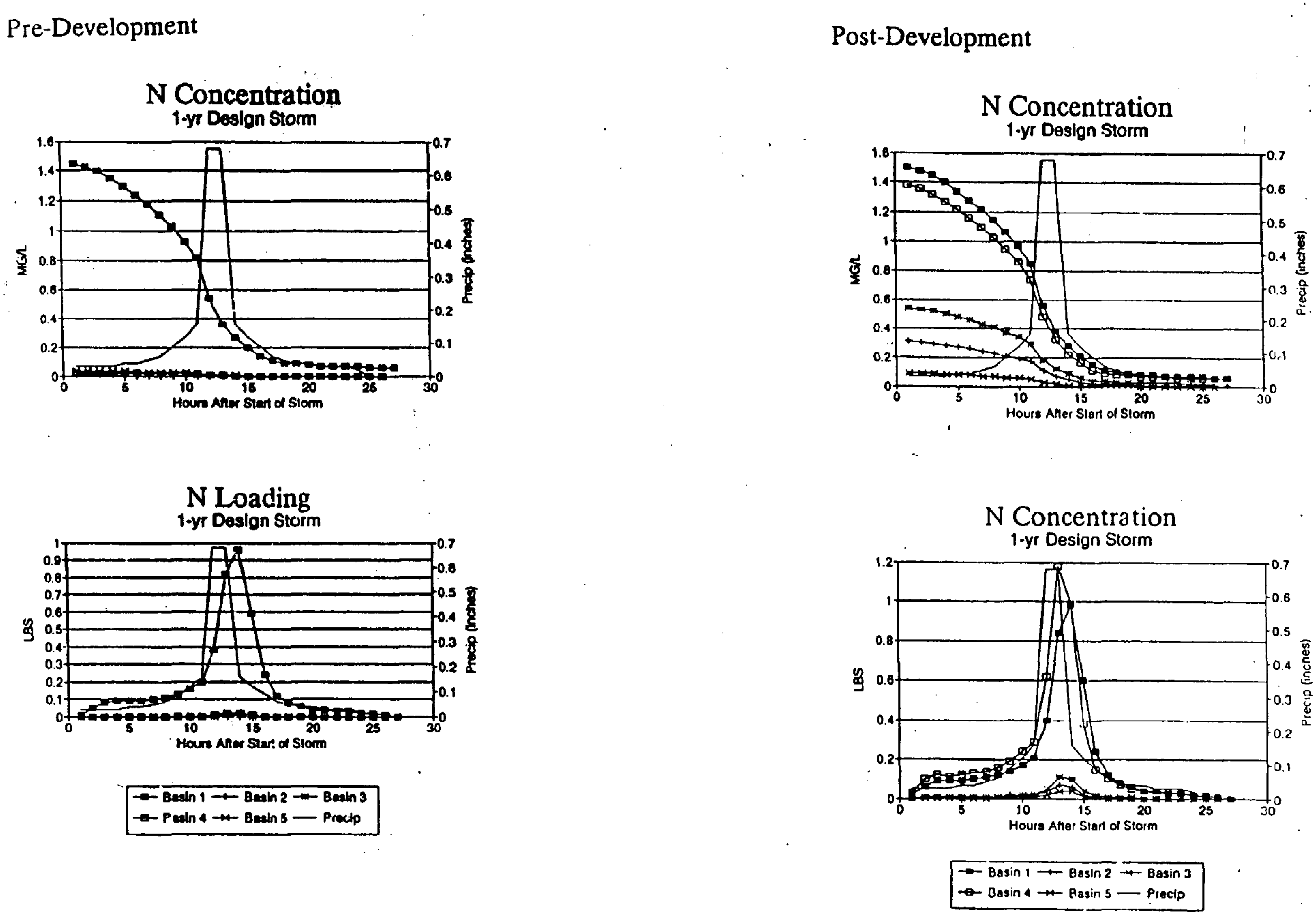


Figure 3. Pre- and Post- Greens at Galloways development nitrogen concentration and loading for the 1-year design storm event.

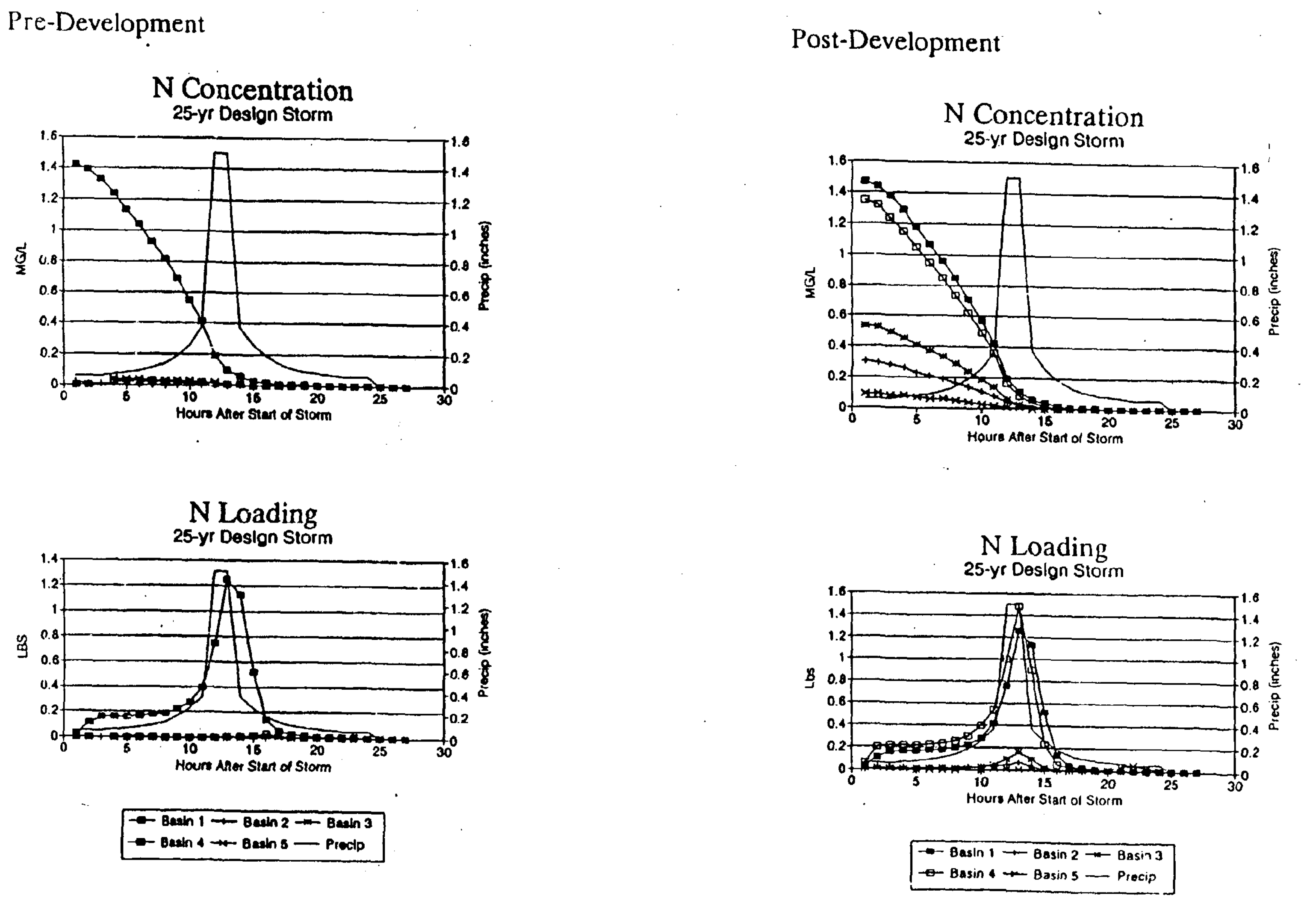


Figure 6. Pre- and Post- Greens at Galloways development nitrogen concentration and loading for the 25-year design storm event.

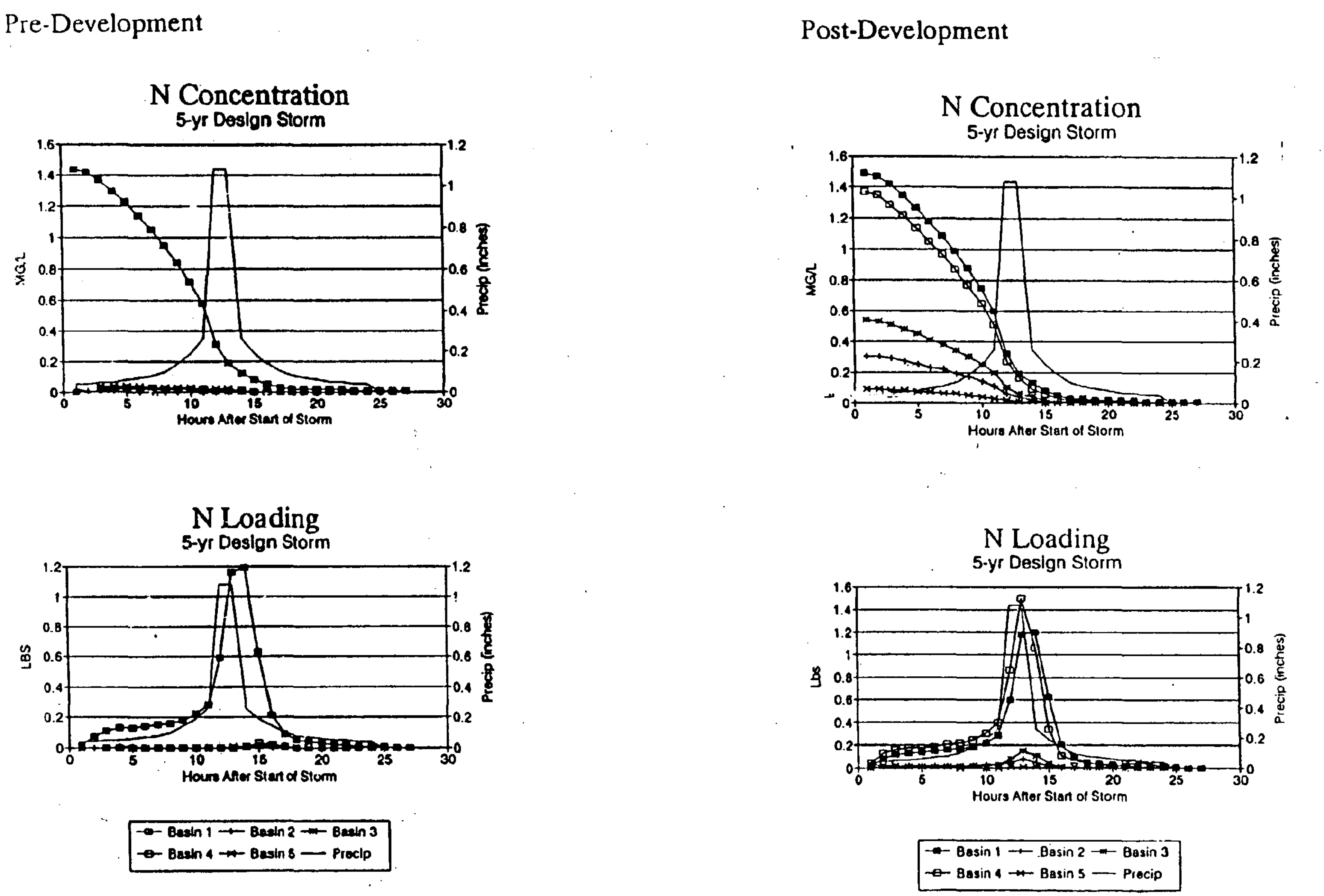


Figure 5. Pre- and Post- Greens at Galloways development nitrogen concentration and loading for the 5-year design storm event.

When the pesticide simulation for Chlorpyrifos was run and calculated for the 100 year storm, the runoff from the subbasins and the non-ponded areas were simulated separately to determine if only the runoff from the non-ponded areas would exceed the EPA(a) limits, and it did. However it is possible that, if the ponds are full from a previous rainfall, and sufficient rainfall enters the ponds, overflow would occur. This overflow is designed to flow into the nonponded areas. This additional runoff would increase the amounts of pesticide entering the streams.

Another potential source of pesticides runing into the waterway of the Refuge would occur when the pesticides are being applied. Wind would carry the spray and deposit pesticide directly into the creeks and/or the Refuge itself. Drift of the pesticides would result in contamination of the wetlands at greater concentration. This resulting contamination, in greater concentrations than in the runoff, would enter the waters of the Refuge.

The above represents situations where the Refuge waters would be degraded through regular, monitored use of the pesticides. Accidental spills, discharges, leaks, inappropriate applications would all contribute to the alteration of the Category One classification of the Refuge's waters.

Runoff from the development will exceed the EPA 304 (a) Criteria for fresh waterways such as the Doughty Creek, at upstream of a C1 waterway, Edwin B. Forsythe National Wildlife Refuge. Immediately upon receipt of, and many years after receipt of the development's runoff changes in water quality may occur. Pesticides, through bioaccumulation, settling, and simple dilution would cause an alteration and degradation in the quality of the waters of the Edwin B. Forsythe National Wildlife Refuge along with the ecological systems intrinsically tied to the waters of the Refuge.

Based on the results of the PRZM model it is concluded that the golf course runoff water would cause significant impact on the ENWFR which would degrade the waters of the ENWFR.

VII.2. Nutrient

The Edwin B Forsythe National Wildlife Refuge (EBFNWR) downstream from Doughty Creek has been designated C1 Waters, which is allowed no degradation in water quality. The proximity of this development to the Bog and the nearly permanent saturation of the soils suggests that nutrients and pesticides would be washed into the Oceanville Bog through runoff and ground water flow. This proposed

VI.3 Pesticides via Groundwater transport

Computation using equations (c) to (f) shows that the seepage velocity is 2.46 ft/day and retardation factor is 1.75. The pesticides carried by subsurface seepage water will take approximately 213 day to reach the receiving water at 300 feet away. This is due to the relatively high K_{OC}s of Pesticides and less steep hydraulic gradient (0.0037 ft/ft based on Spring Mill Drive, Galloway Township's data as reported by Bureau of Wellfield Remediation, 1/1992) in subsurface flows. As a result, the impact to the receiving water through ground water will not be an immediate impact. Therefore, the computation of concentration (average and maximum) for pesticides from pond water seepage reaching the receiving water were not performed.

However, it should be kept in mind that this is only a rough estimation due to insufficient data for estimations of ground water related coefficients.

As far as ground water pollution is concerned, the time for vertical seepage of pollutants from the rention ponds to the ground water will depend on the depth of ground water table, soil types, and moisture content of soil beneath them. In this study it is expected to be short. This is due to the fact that the dominant soil types, Downer and Sassafras soil, are considered to be of relatively high infiltration rate (soil type B) and moderate rapid permeability (approximately 8 ft/day). However, due to insufficient information of local ground water profile, the computation of time for pesticides to reach the ground water was not conducted.

VII. *DISCUSSION and CONCLUSION*

VII.1 Pesticides

As a result of running PRZM, it was predicted that pesticides used on the golf course will cause water quality change in measurable amount in the runoff emanating from the development. The possible routes for runoff carrying pesticides are overland flow into the bordering creeks feeding Lily Lake which drains directly into the Refuge or enters the ponds which will seep into ground water.

The above results represent concentrations for each individual pesticide. However, during a storm the runoff would be composed of all of the various pesticides applied to the golf course and synergistic or additive effect of these pesticides in the runoff would therefore be much greater thereby increasing the impact to the biota in both Doughty Creek and the unnamed creek.

development and the alternate plan to build more residential units would impact this system and degrade the water quality through the introduction of nutrients and pesticides.

This conclusion is supported by the preliminary results obtained from the PRZM and STORM models. Both models show that pesticides and nutrients will be washed off the golf course into the Bog. The STORM output shows a tremendous increase in nutrients, which would promote algal growth and cause eutrophication, will runoff into the Bog.

VII.3. Pollution impact via ground water

As stated, insufficient site information has hindered a thorough assessment for this development. The required information for more thorough analysis includes the depth to groundwater table, thickness of aquifer, hydraulic conductivities for soils at pond location, hydraulic gradients between ponds and receiving waters.

VIII. MISCELLANEOUS

Part of the Seaview County Club Golf Course lies within the 1,948 acre drainage system. Assessment of the pesticides in runoff water from this golf course was neither included nor calculated in this assessment. It is anticipated that the pesticide concentration in receiving water will be higher than predicted if the loading from the Seaview golf course was taken into consideration.

For two pesticides, Maneb and Thiram, a breakdown product is Ethylene thiourea. As per EPA's data, the carcinogen classification status of Ethylene thiourea is pending.

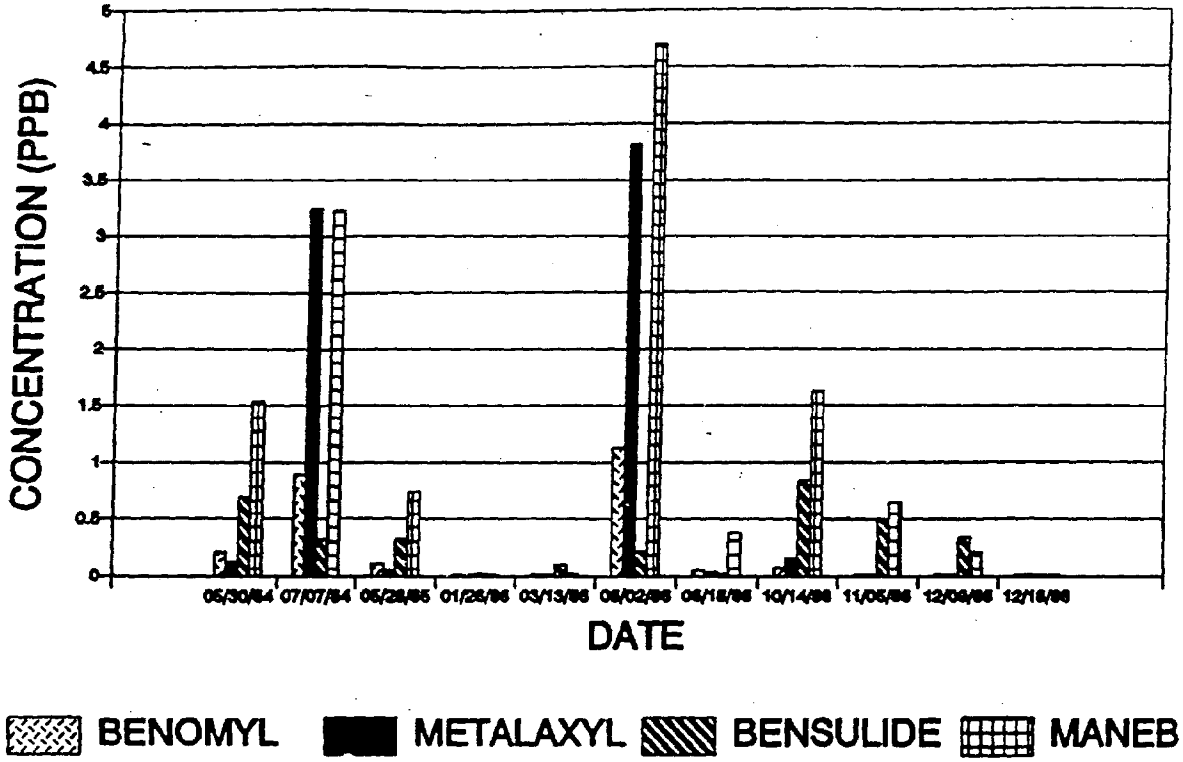
Roof rainwater runoff is proposed to be captured by below ground seepage pits. As per Joe Reitzes of the Bureau of Construction and Connections, 984-4429, such pits are illegal.

Reference

Najarian, Thatcher & Associates, Inc., "Assessment of surface and subsurface water quality changes resulting from the proposed development at the towne of historic Smithville" prepared for Historic Smitheville Development Company, Smithville, NJ, 1982.

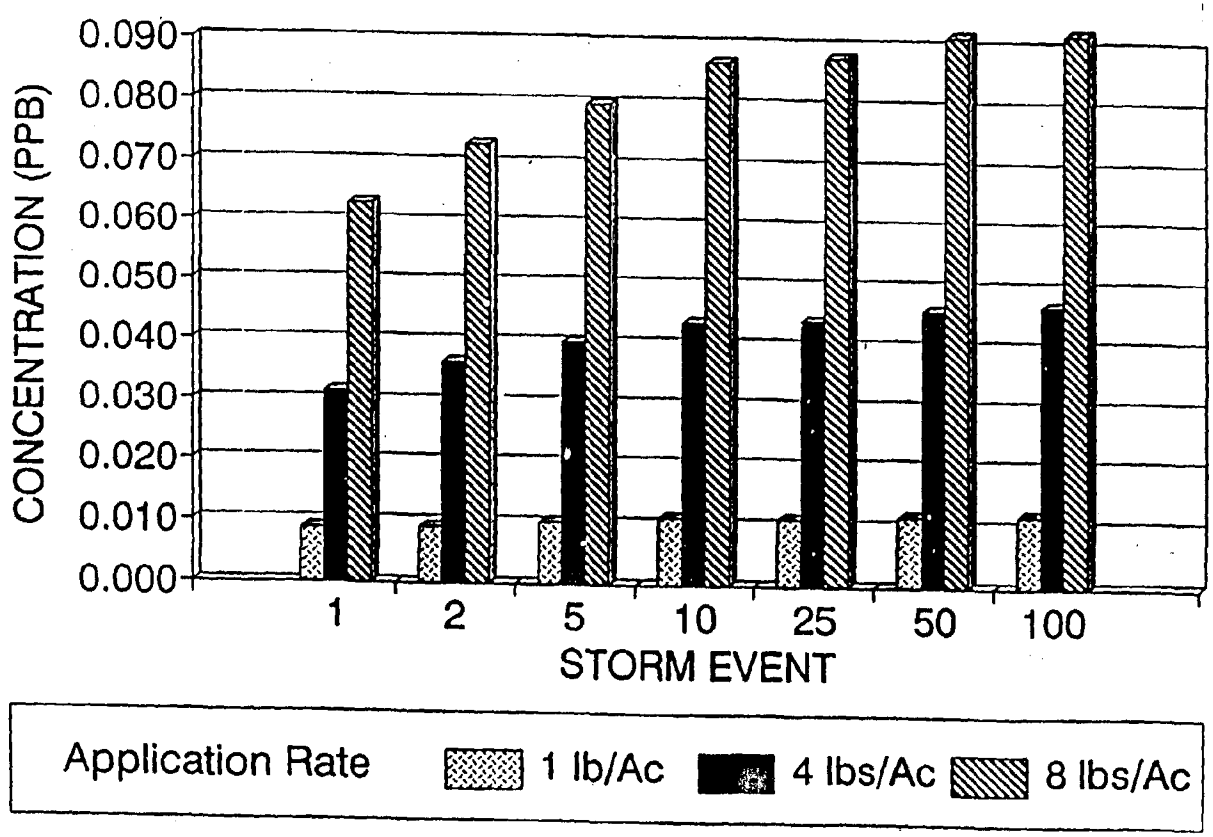
NJDEPE, "Upper Millstone River Runoff Study", 1991.

INSTREAM CONCENTRATION OF PESTICIDES FROM NON-PONDED AREA



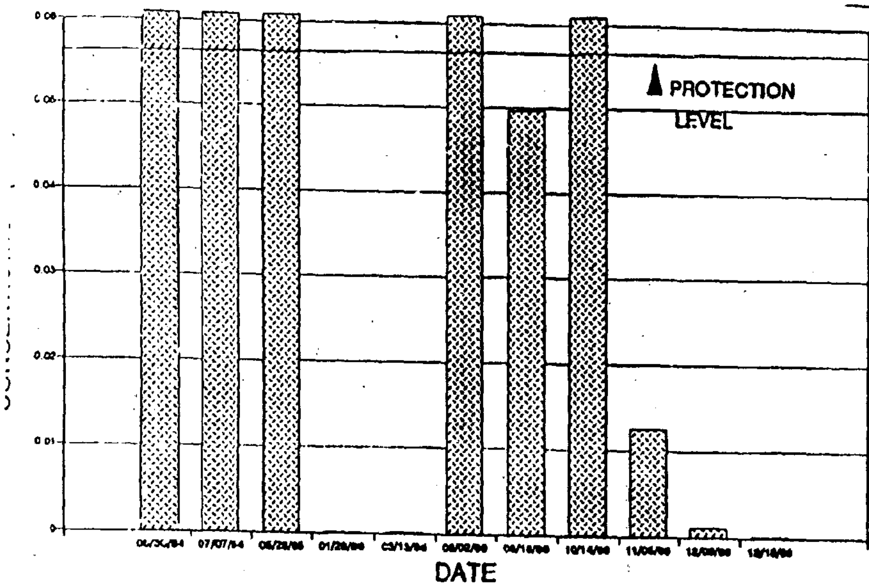
AQUATIC PROTECTION LEVELS: BENOMYL: 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CHLORPYRIFOS INSTREAM CONCENTRATION
Greens

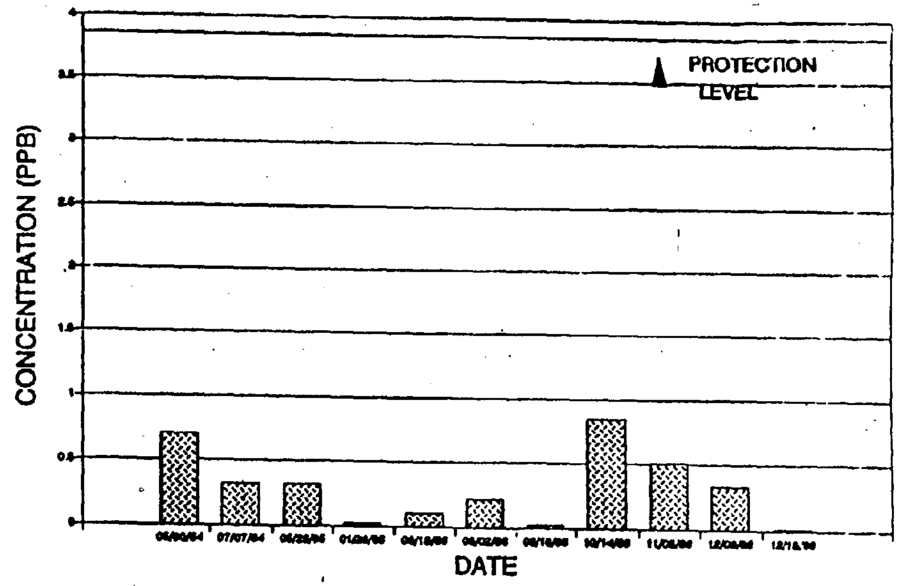


LIMITS:	ACUTE	CHRONIC
Freshwater:	0.083 PPB	0.041 PPB
Saltwater:	0.011 PPB	0.0056 PPB

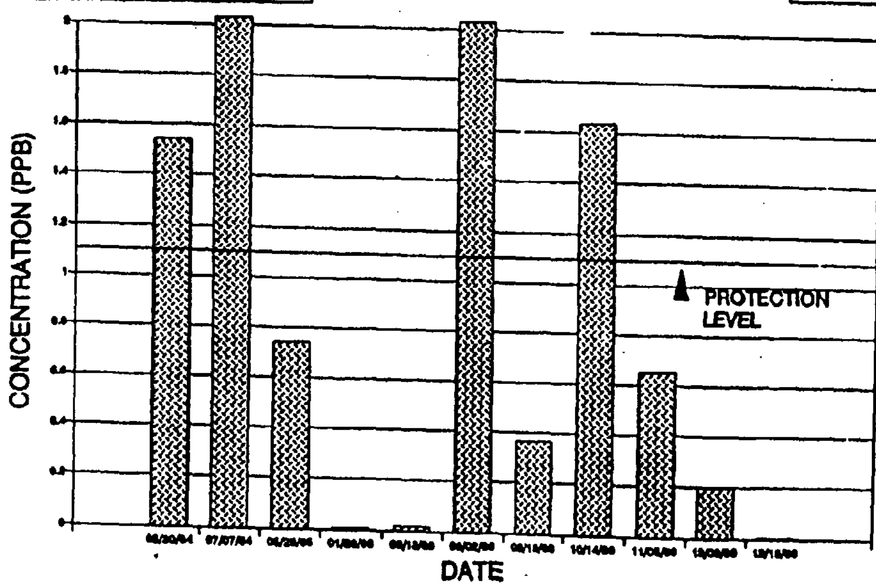
INSTREAM CONCENTRATION OF PESTICIDES FROM NON-PONDED AREA



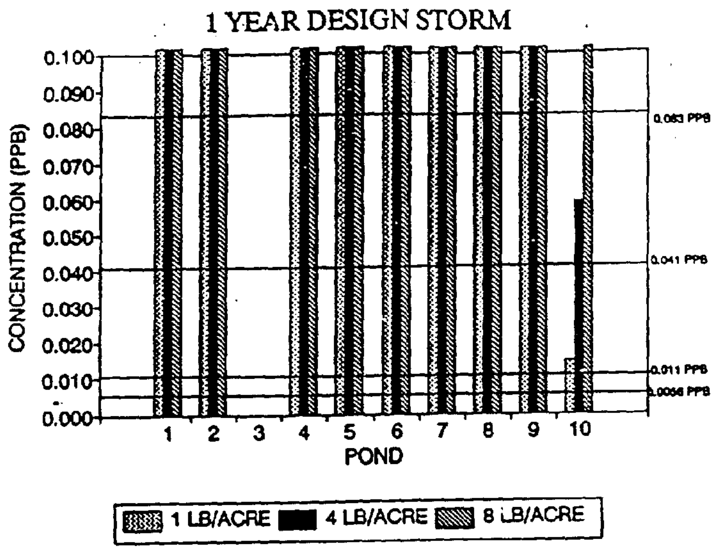
BENOMYL AQUATIC PROTECTION LEVEL: 0.056 PPB

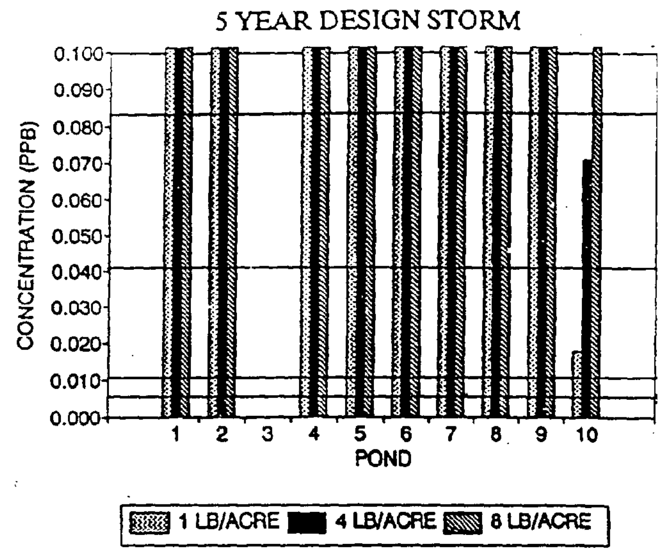


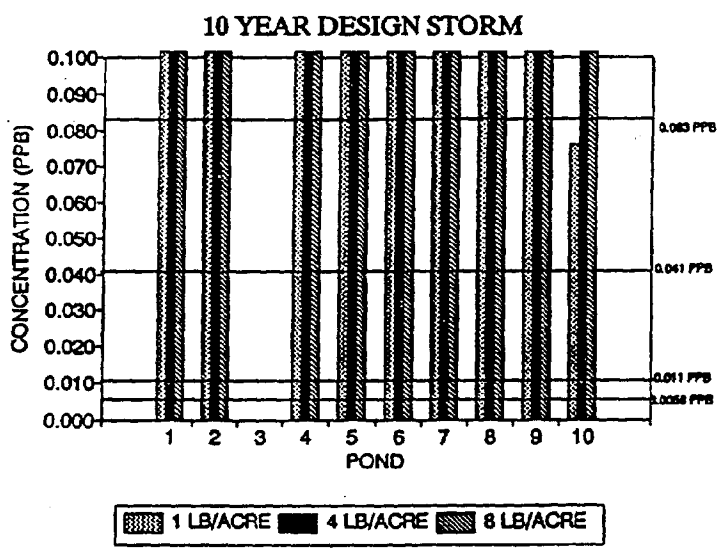
BENSULIDE AQUATIC PROTECTION LEVEL: 3.79 PPB

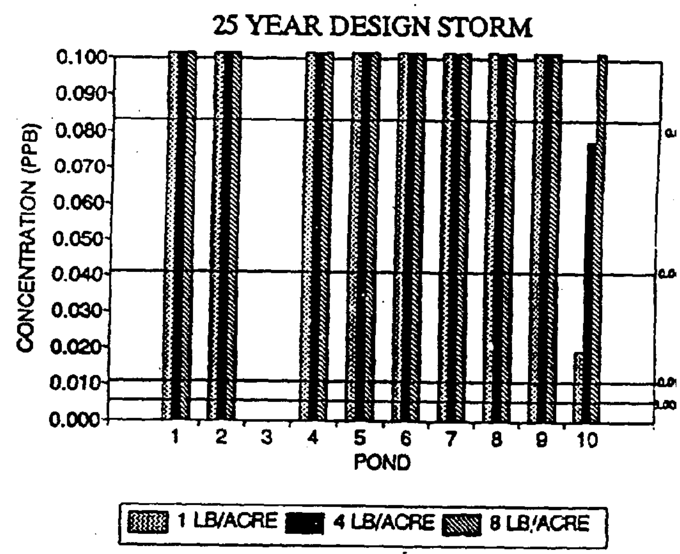


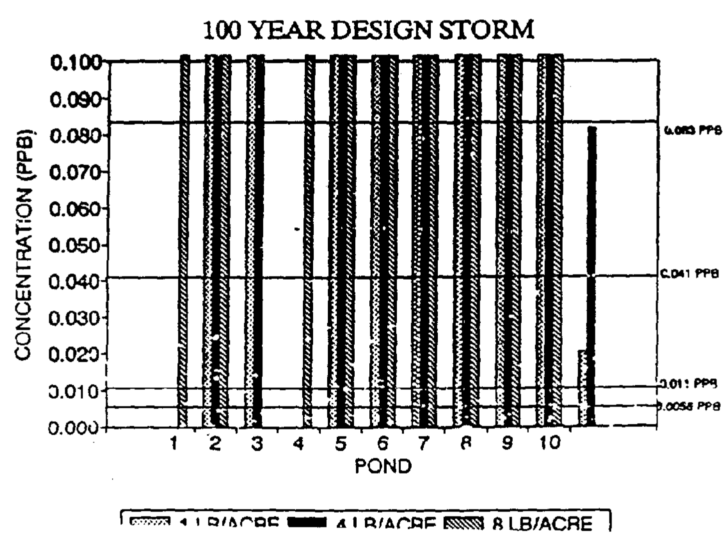
CONCENTRATION OF CHLORPYRIFOS IN RUNOFF ENTERING PONDS



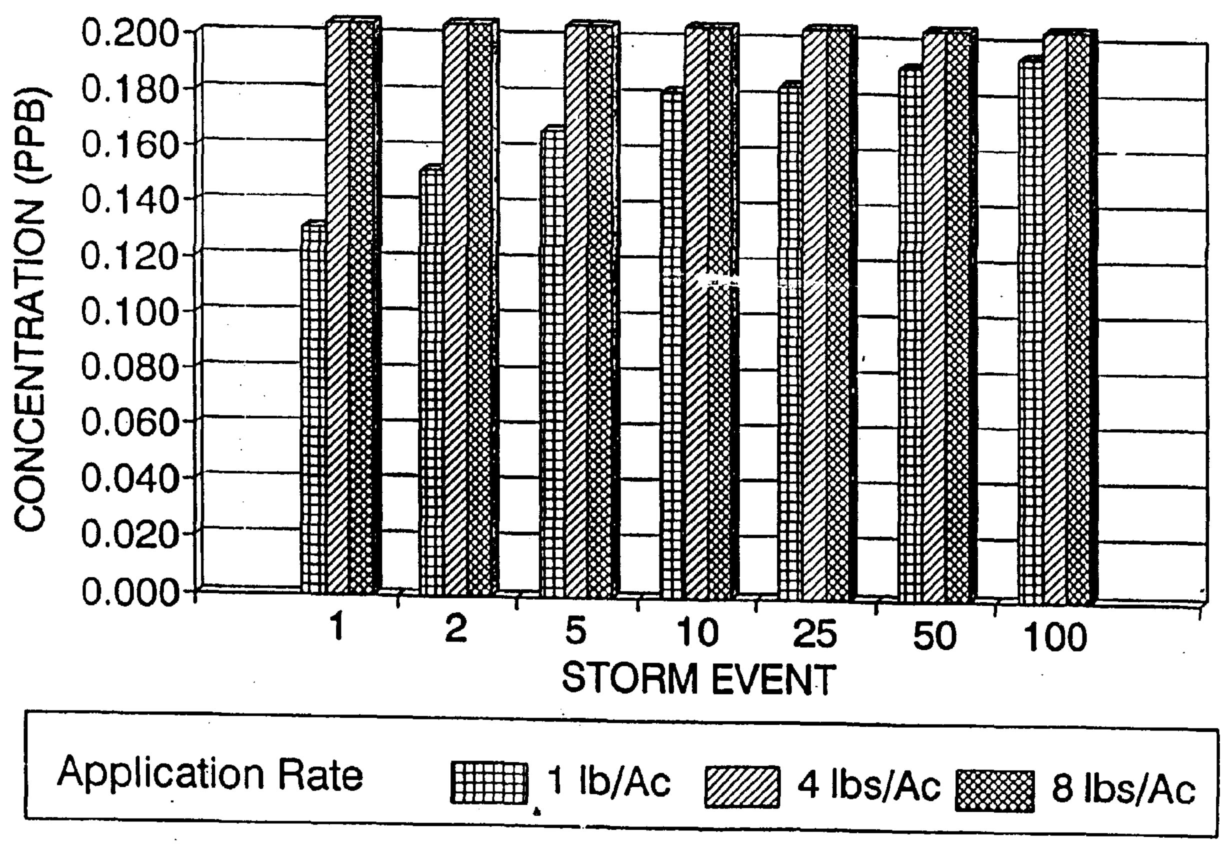






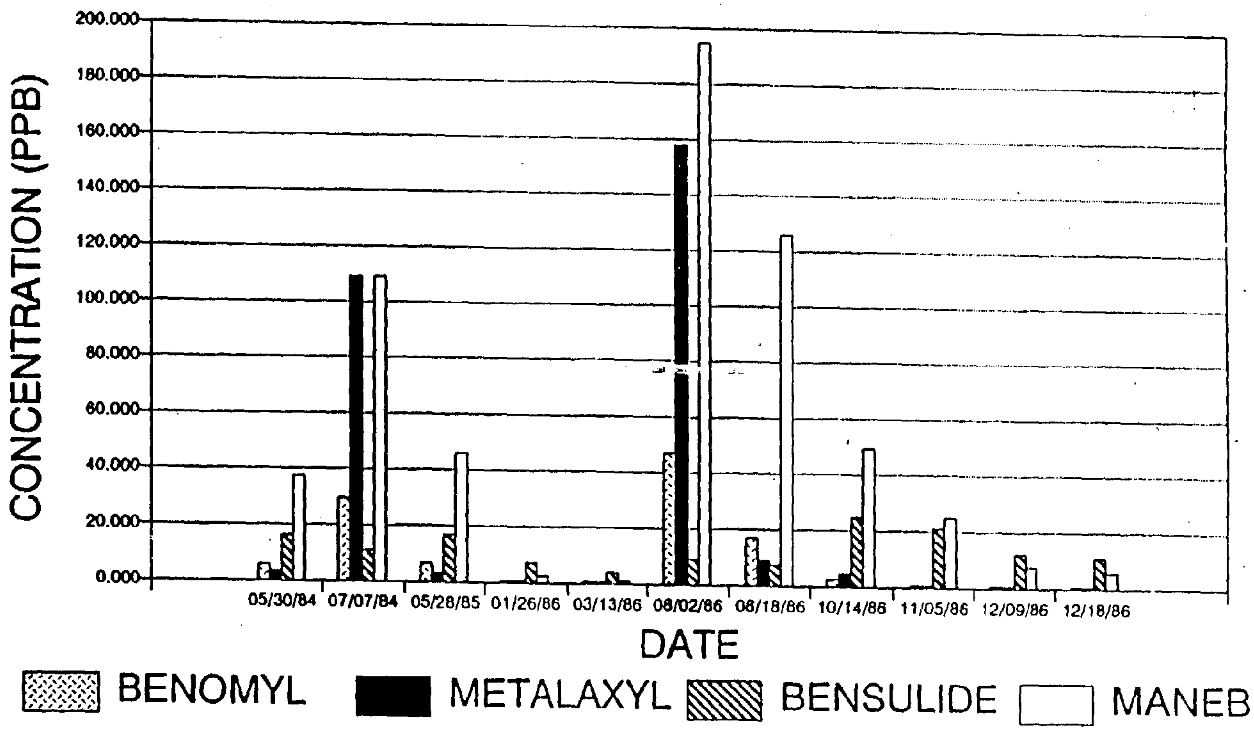


CHLORPYRIFOS INSTREAM CONCENTRATION
Fairways



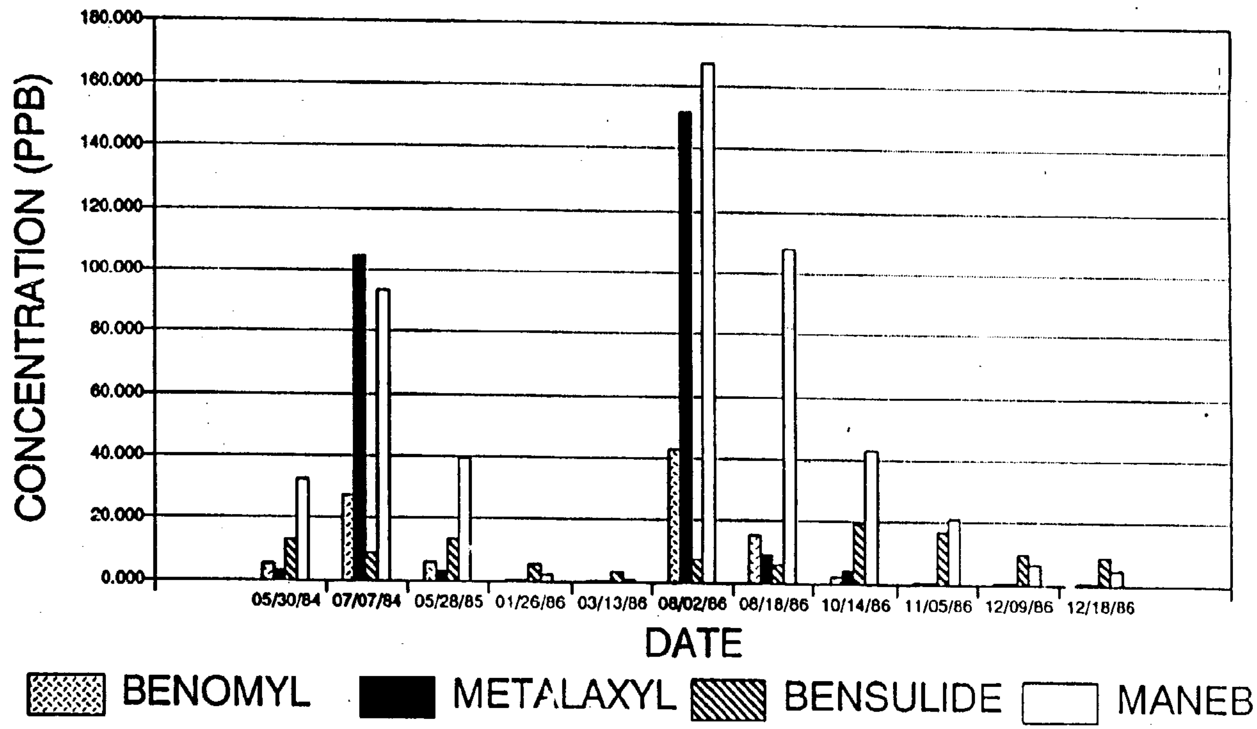
LIMITS:	ACUTE	CHRONIC
Freshwater:	0.083 PPB	0.041 PPB
Saltwater:	0.011 PPB	0.0056 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 2

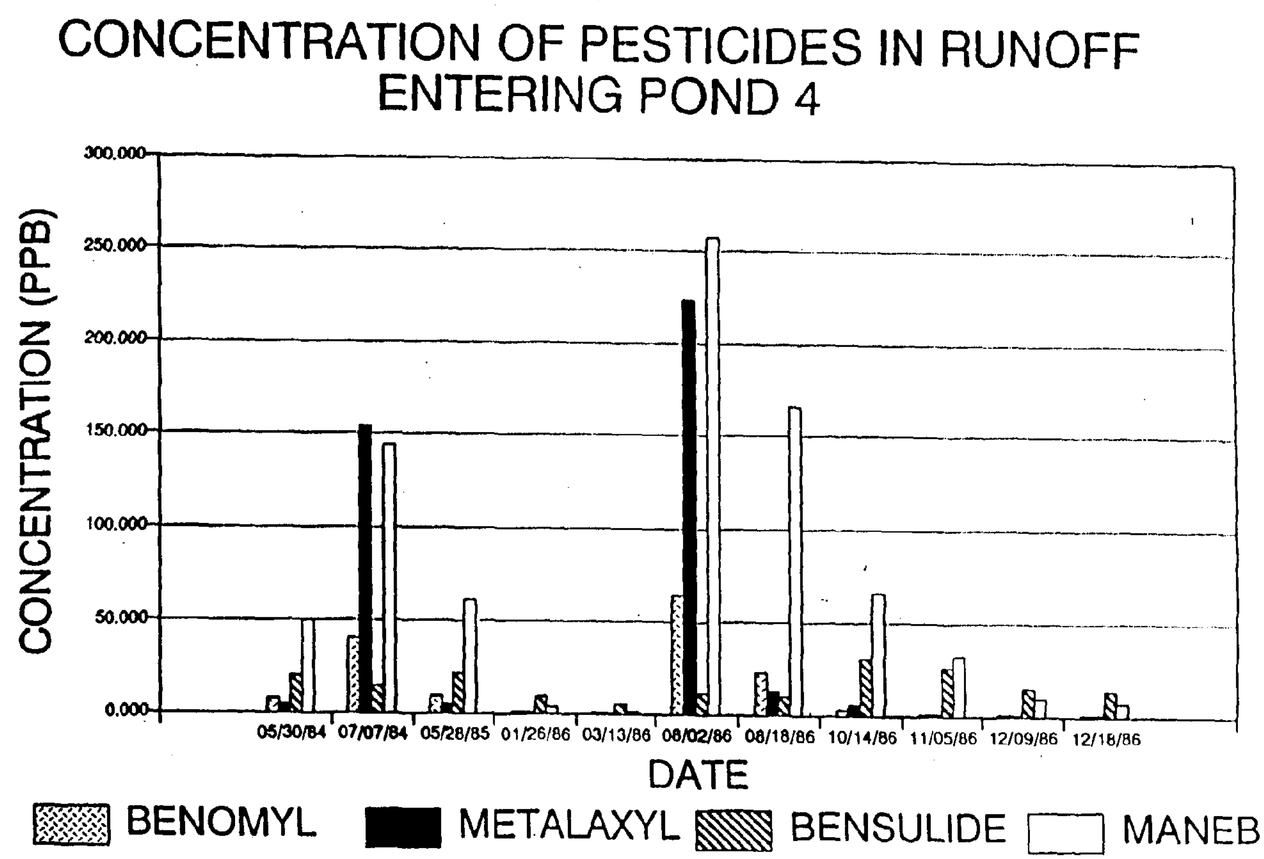


AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 1

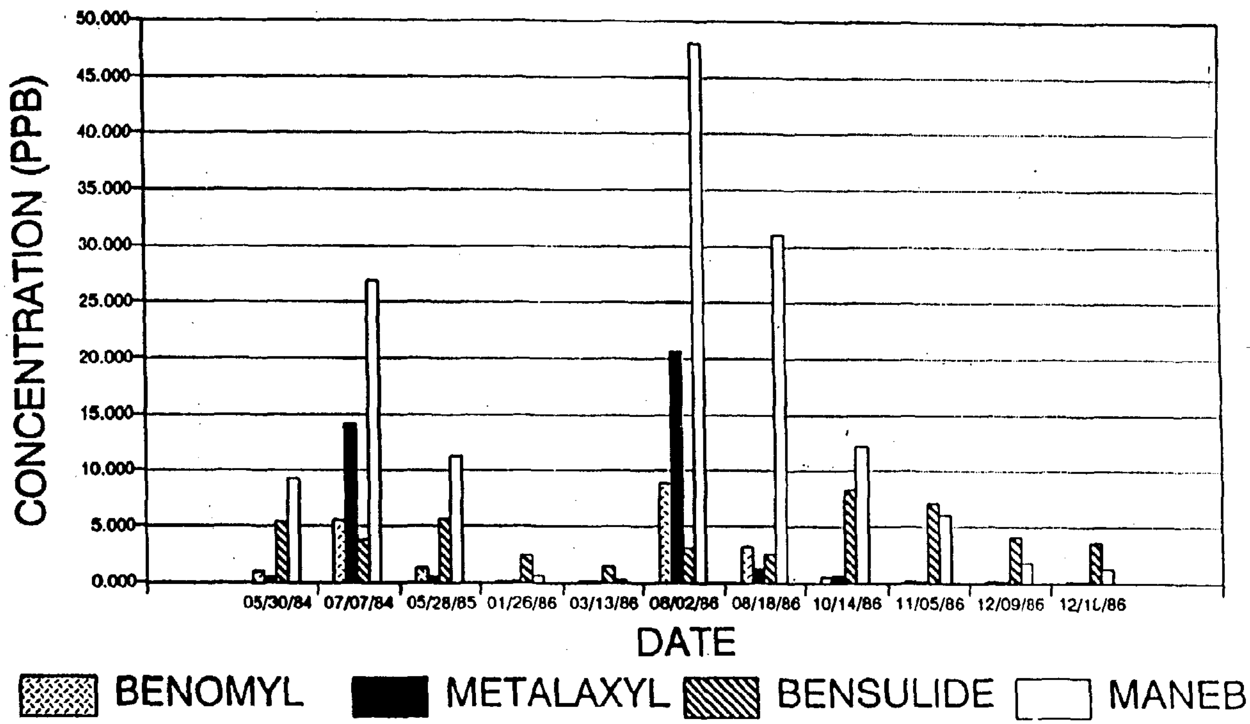


AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB



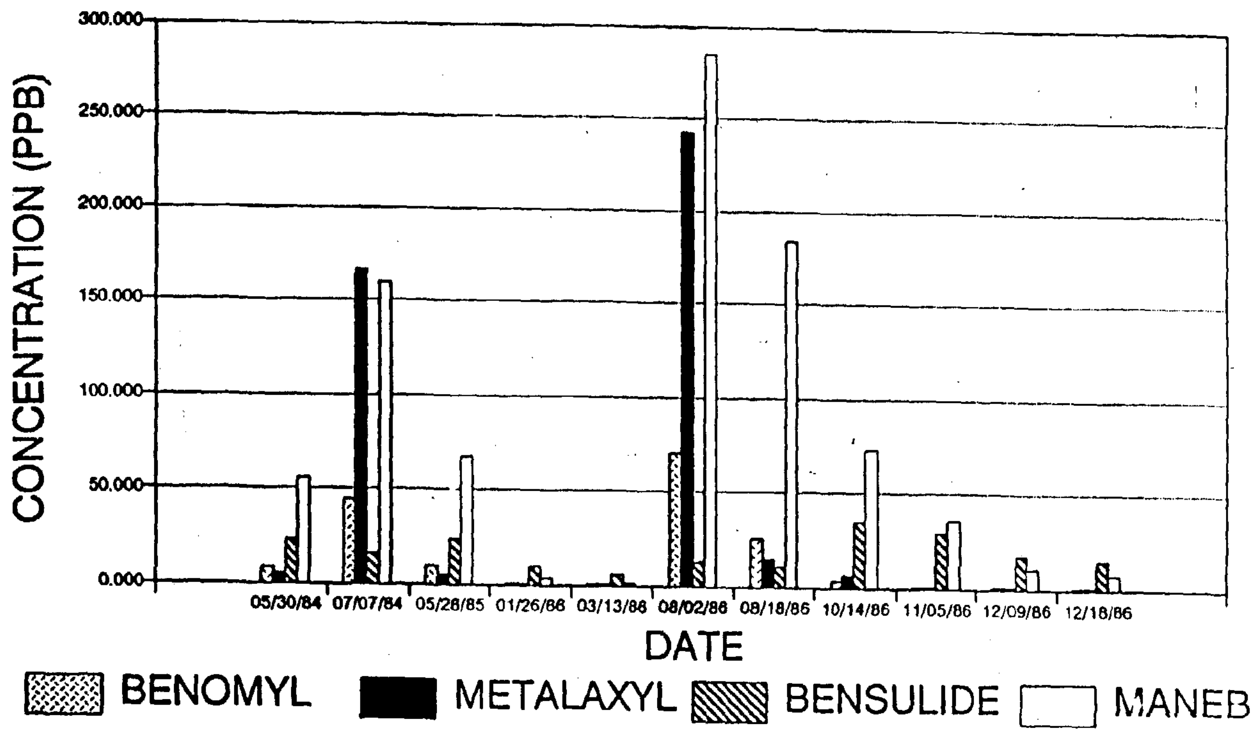
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 3



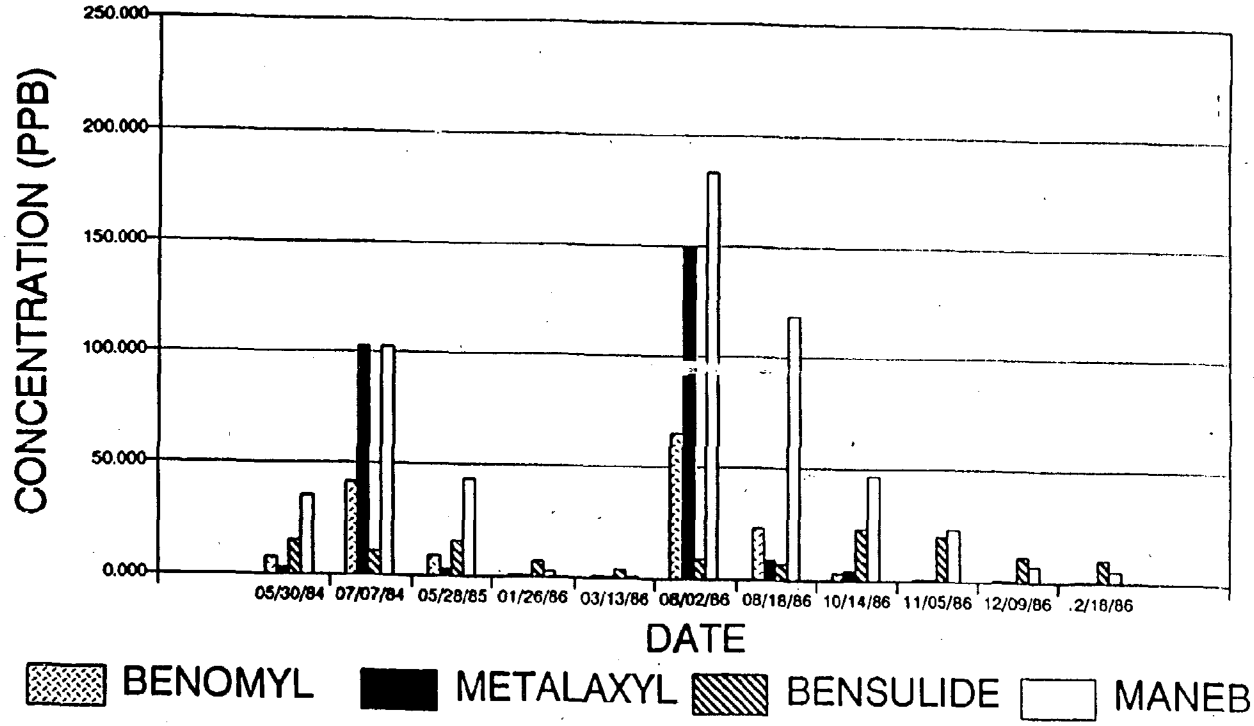
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 5



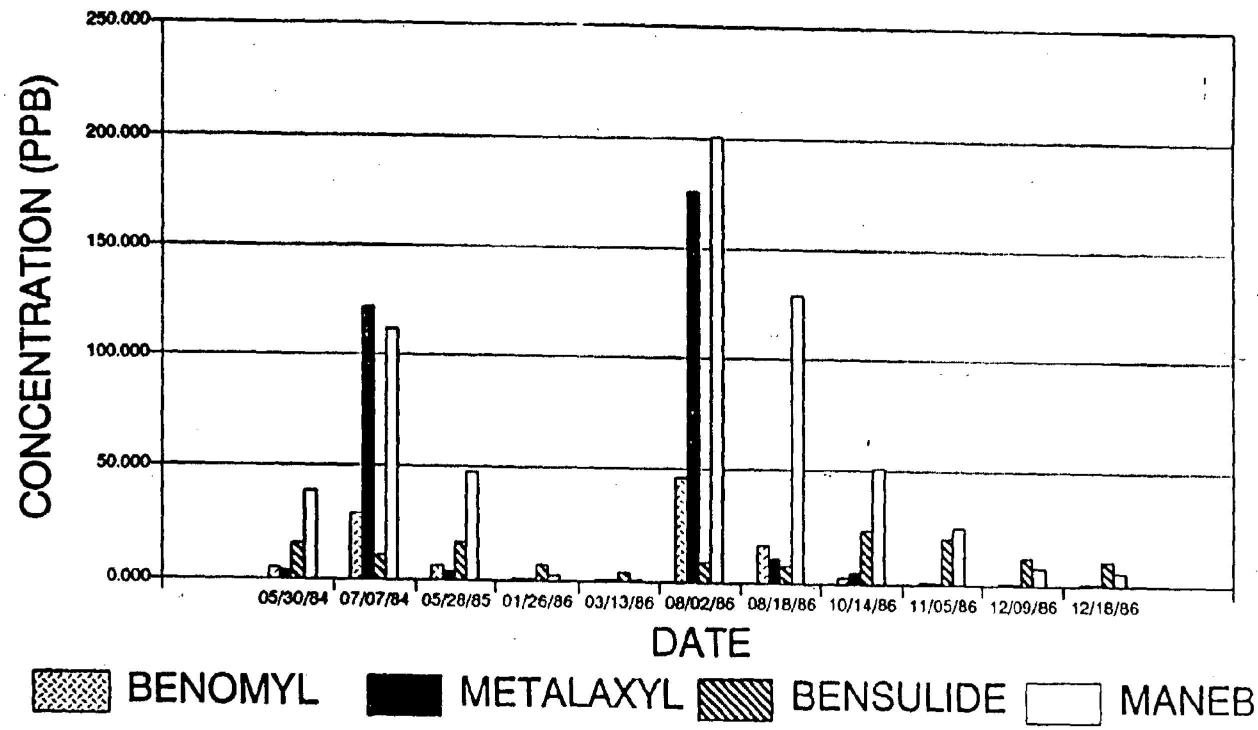
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 6



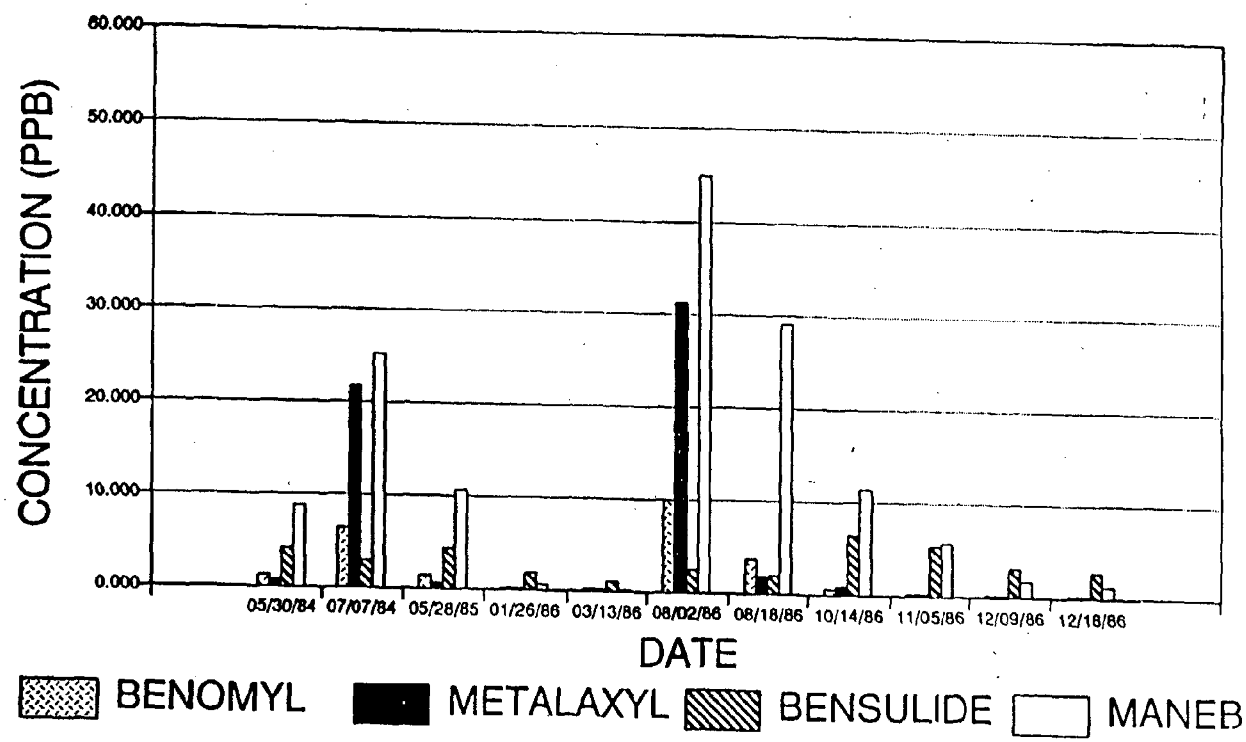
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 7



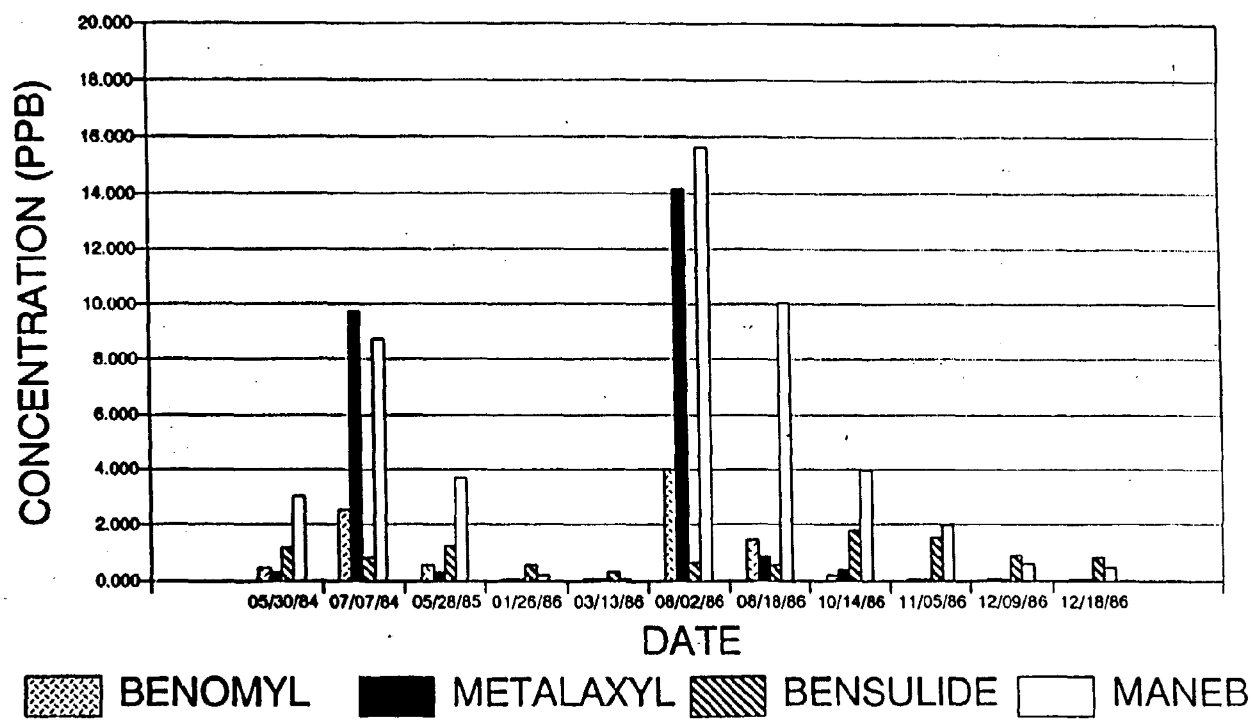
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 8



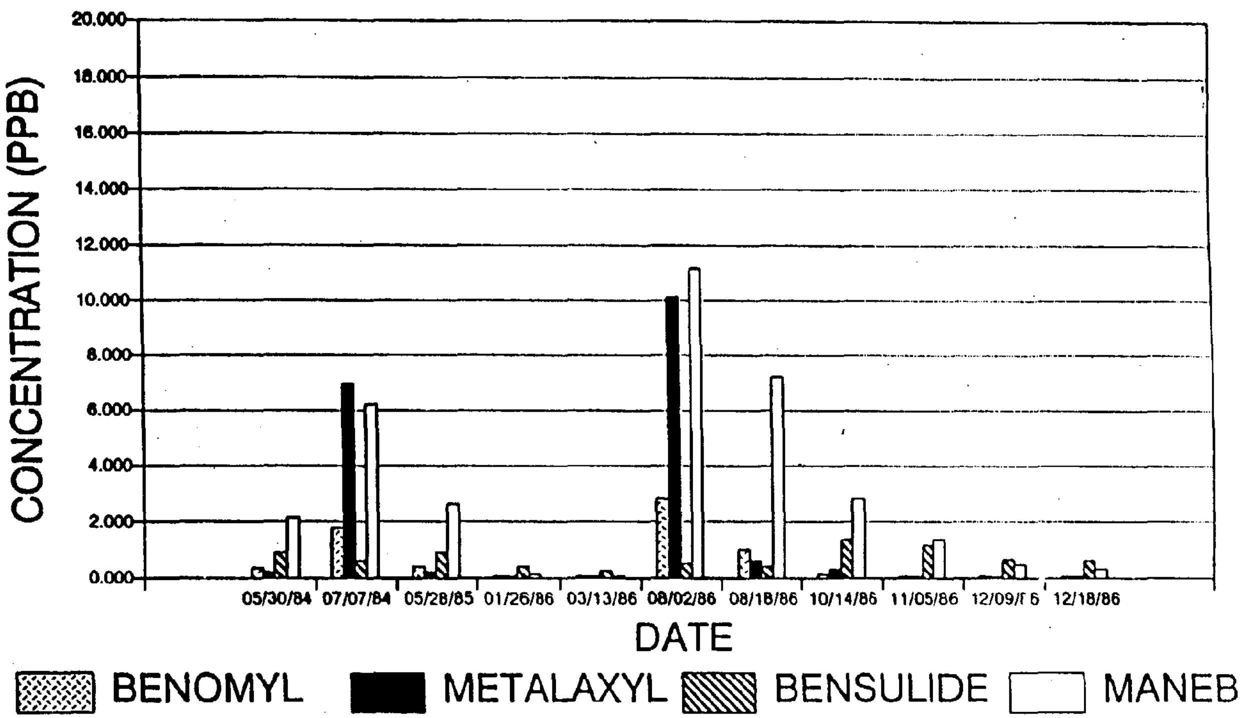
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 9



AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

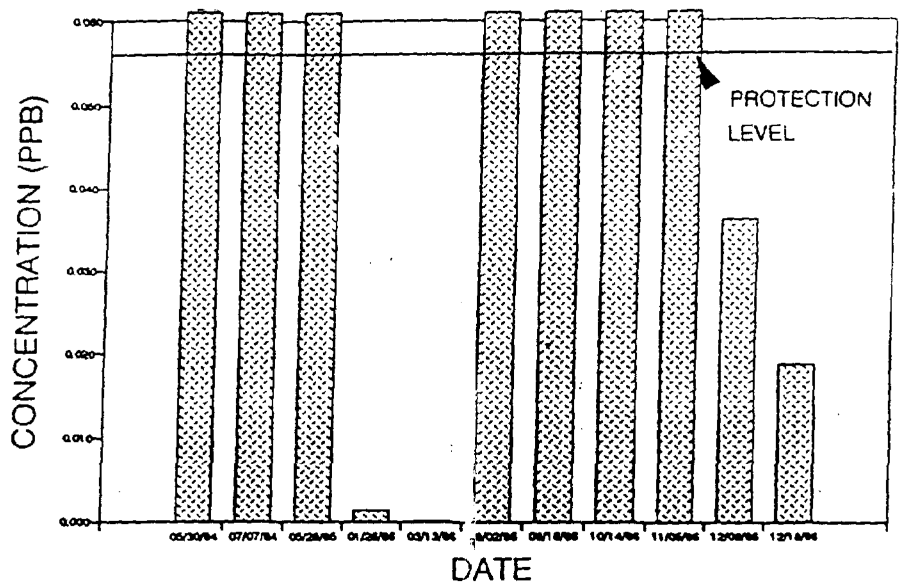
CONCENTRATION OF PESTICIDES IN RUNOFF ENTERING POND 10



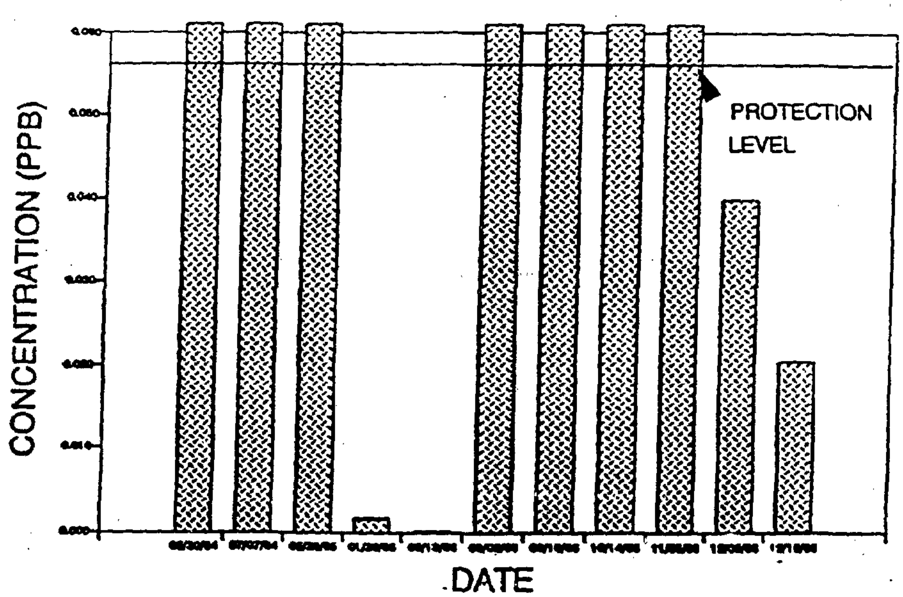
AQUATIC PROTECTION LEVELS: BENOMYL 0.056 PPB BENSULIDE: 3.79 PPB MANEB: 1.10 PPB

CONCENTRATION OF BENOMYL IN RUNOFF ENTERING PONDS

POND 1



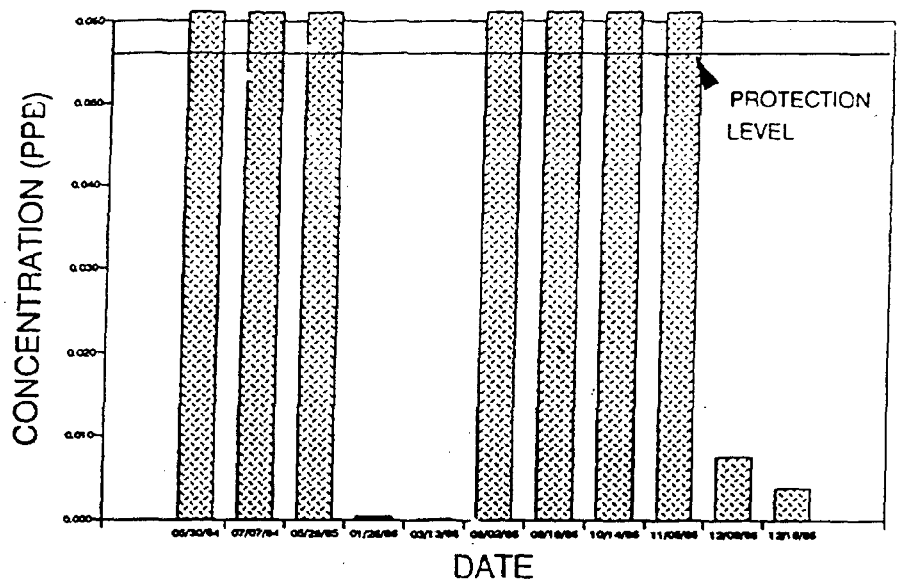
POND 2



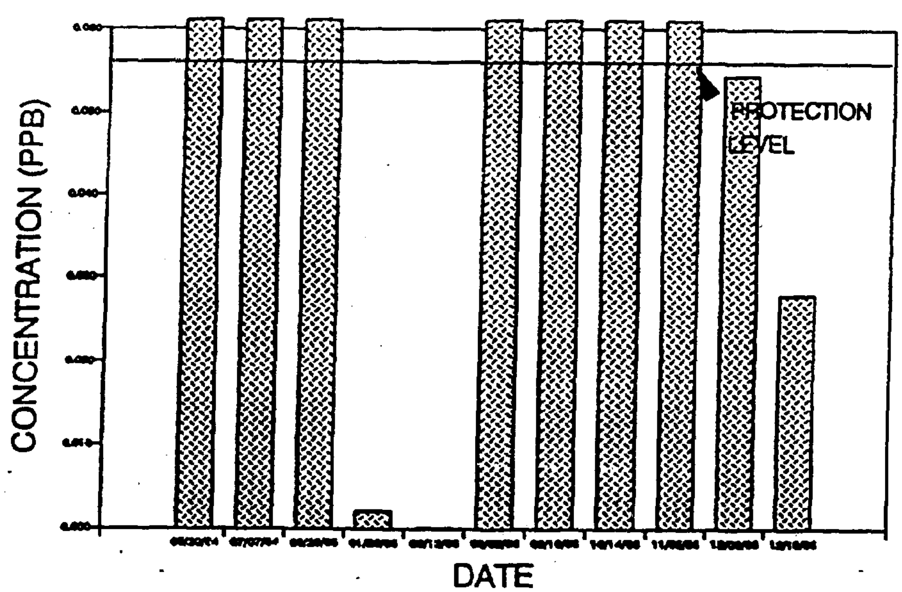
BENOMYL AQUATIC PROTECTION LEVEL = 0.056 PPB

CONCENTRATION OF BENOMYL IN RUNOFF ENTERING PONDS

POND 3



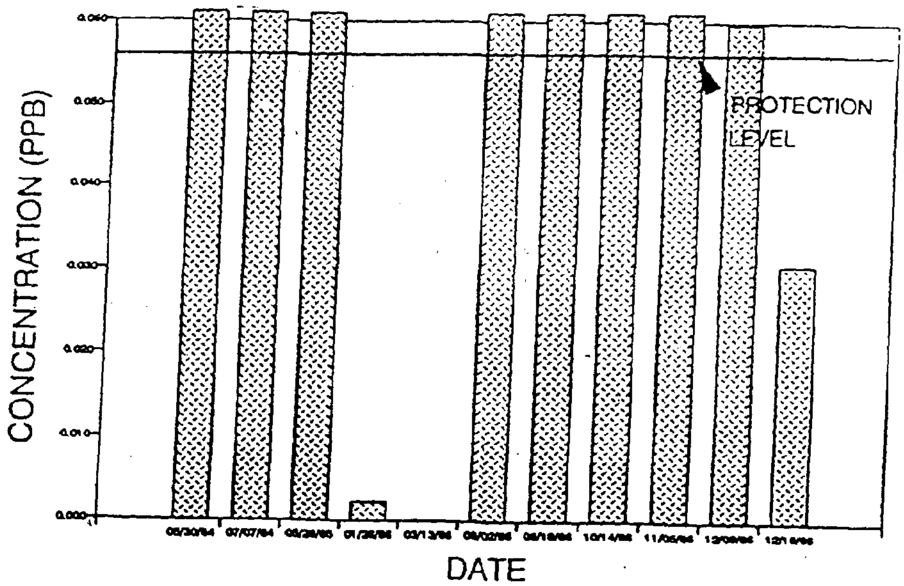
POND 4



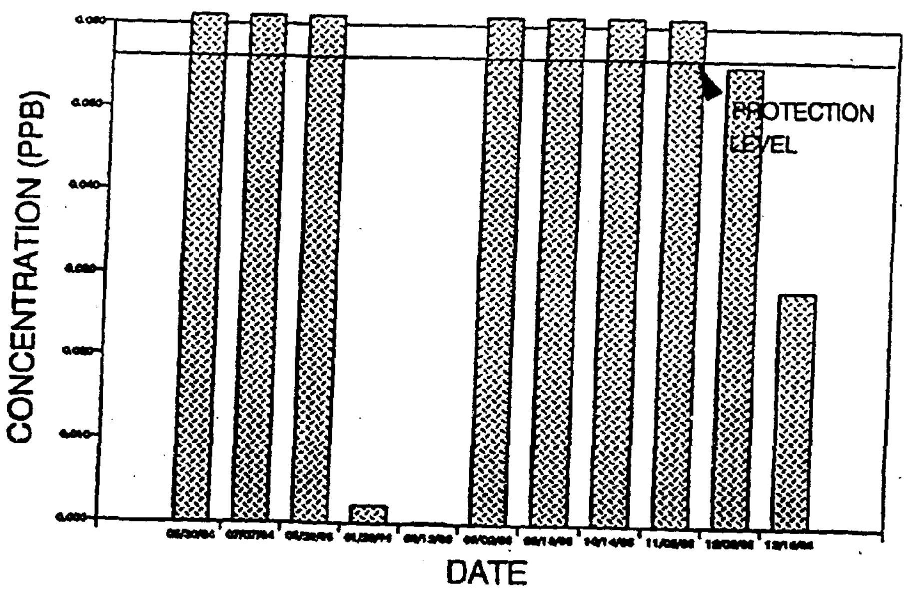
BENOMYL AQUATIC PROTECTION LEVEL = 0.056 PPB

CONCENTRATION OF BENOMYL IN RUNOFF ENTERING PONDS

POND 5



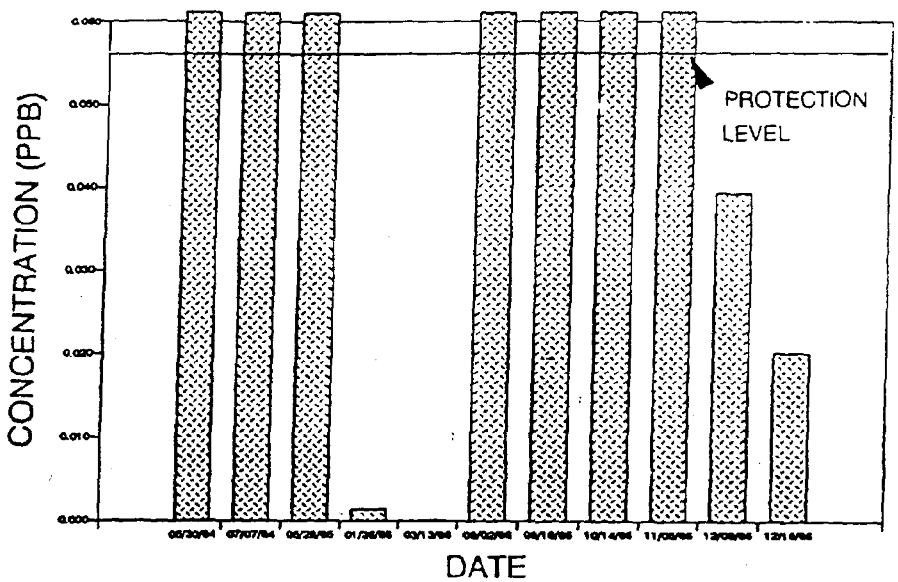
POND 6



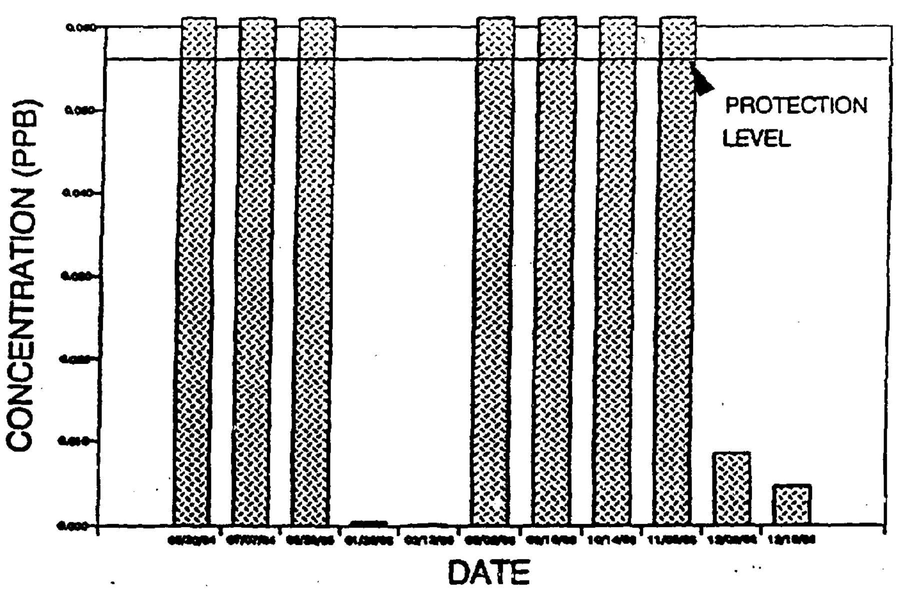
BENOMYL AQUATIC PROTECTION LEVEL = 0.056 PPB

CONCENTRATION OF BENOMYL IN RUNOFF ENTERING PONDS

POND 7



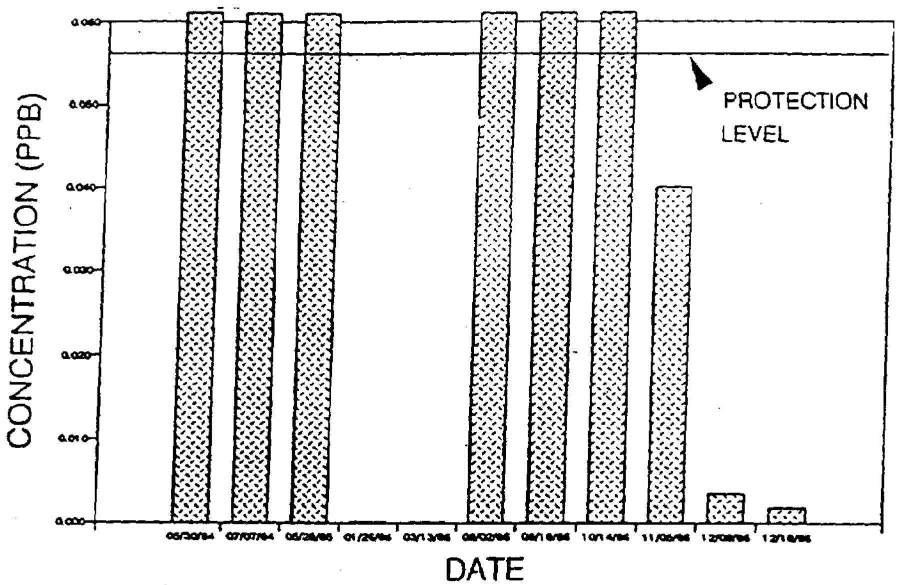
POND 8



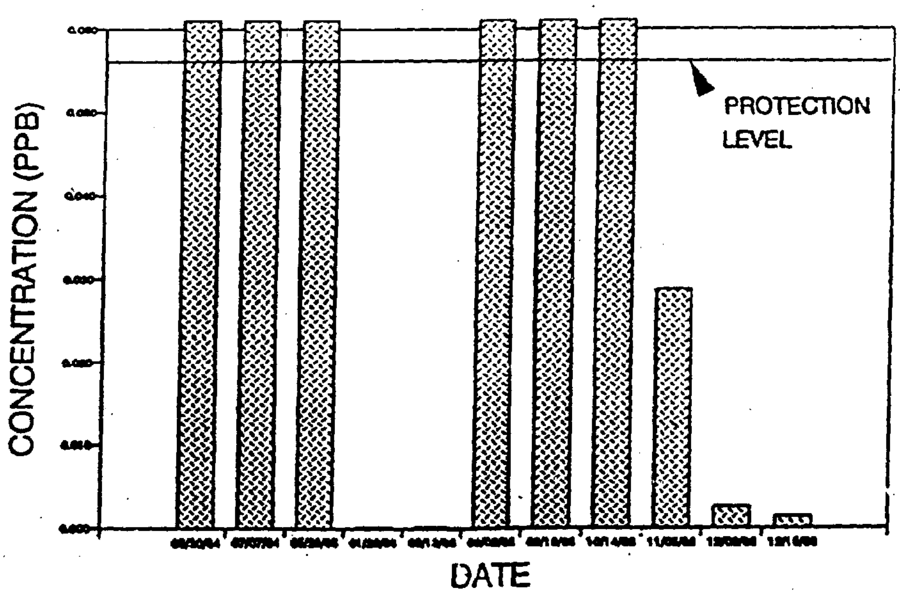
BENOMYL AQUATIC PROTECTION LEVEL = 0.056 PPB

CONCENTRATION OF BENOMYL IN RUNOFF ENTERING PONDS

POND 9



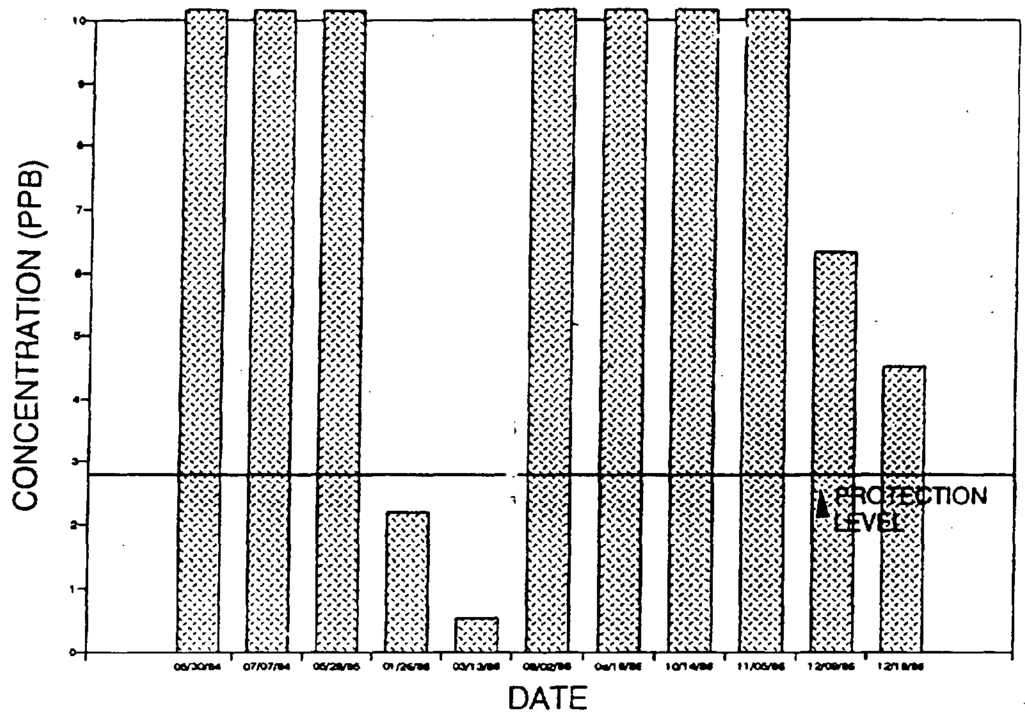
POND 10



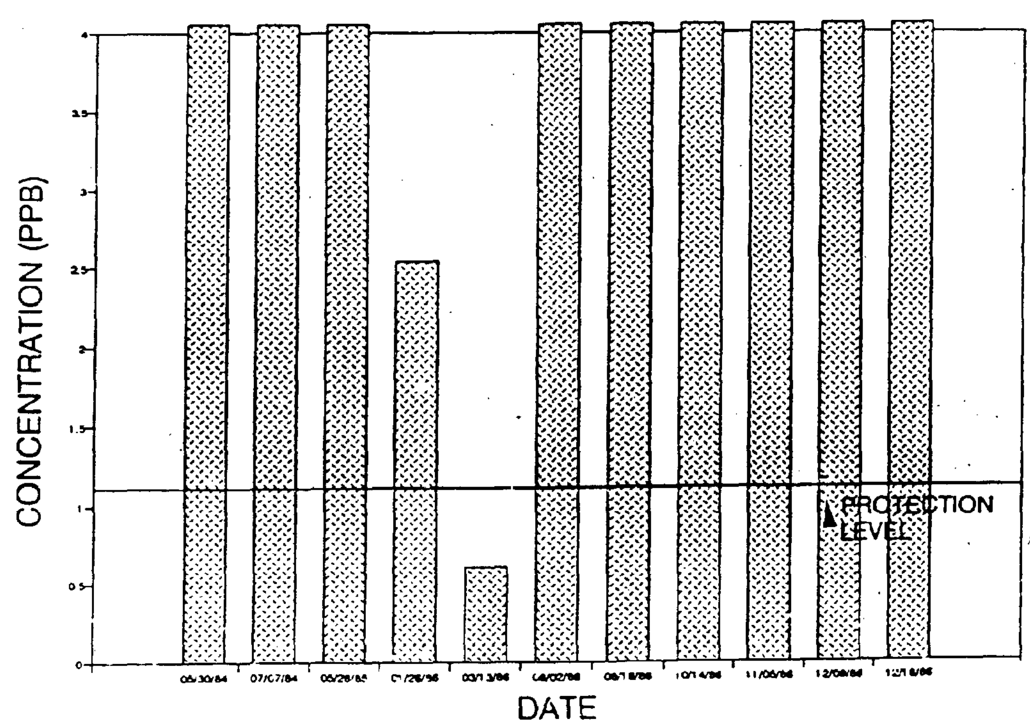
BENOMYL AQUATIC PROTECTION LEVEL = 0.056 PPB

CONCENTRATION OF MANEB IN RUNOFF ENTERING PONDS

POND 1



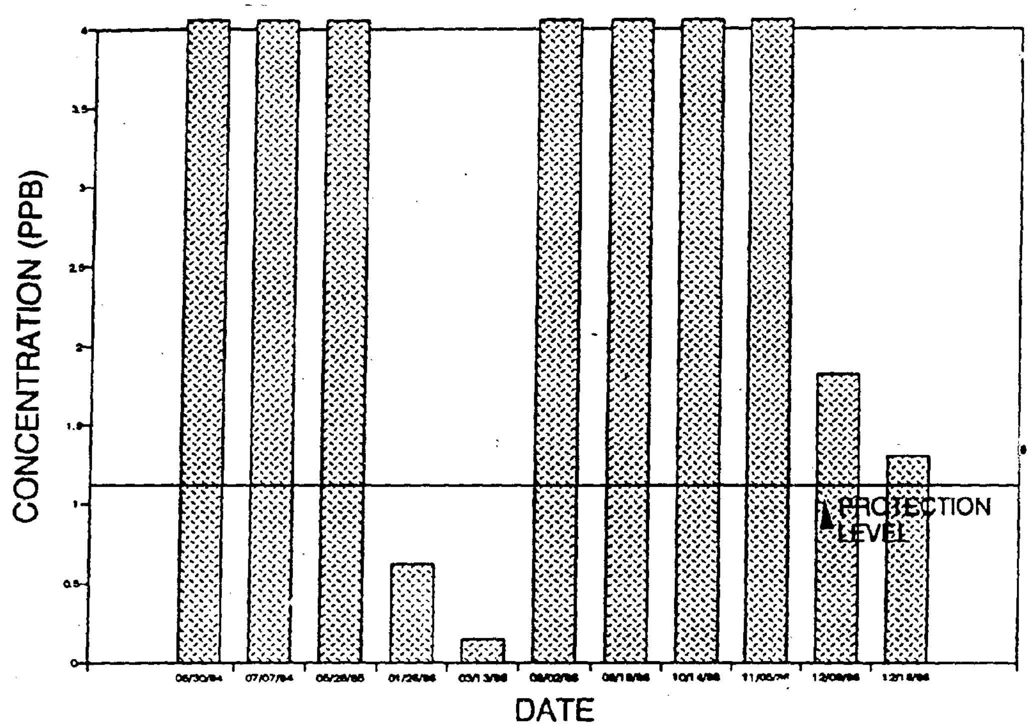
POND 2



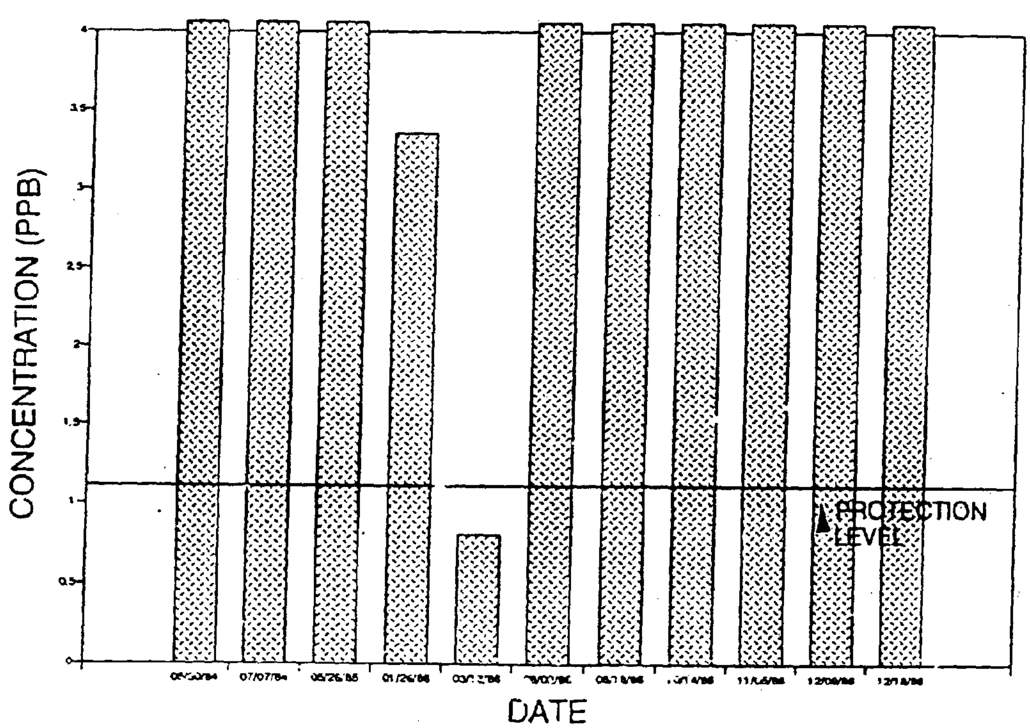
MANEB AQUATIC PROTECTION LEVEL = 1.10 PPB

CONCENTRATION OF MANEB IN RUNOFF ENTERING PONDS

POND 3



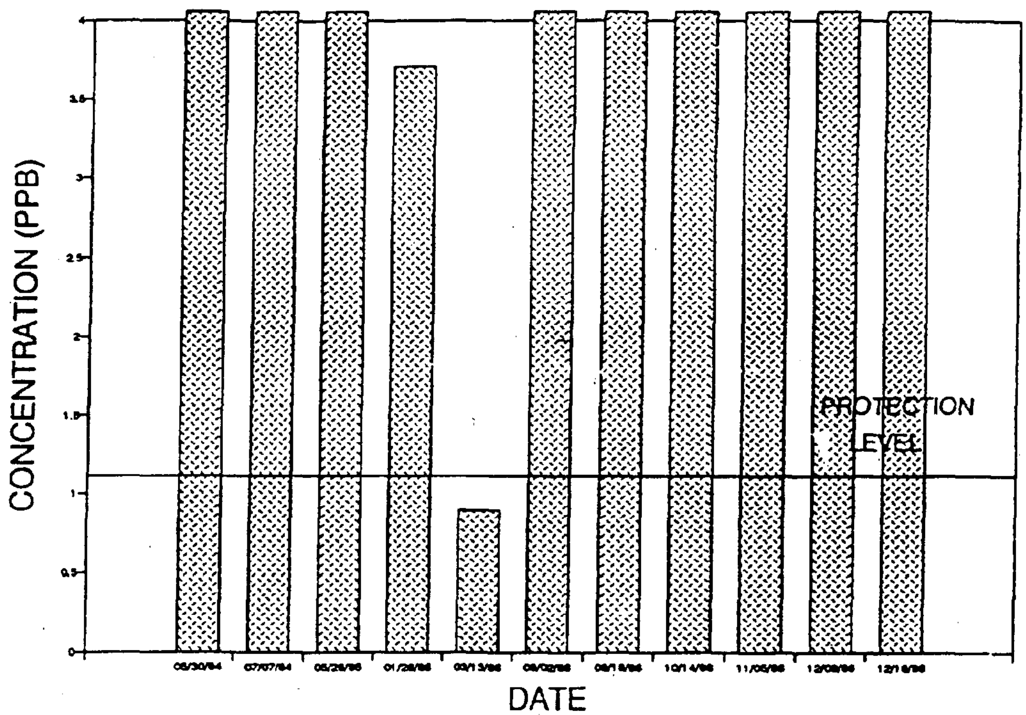
POND 4



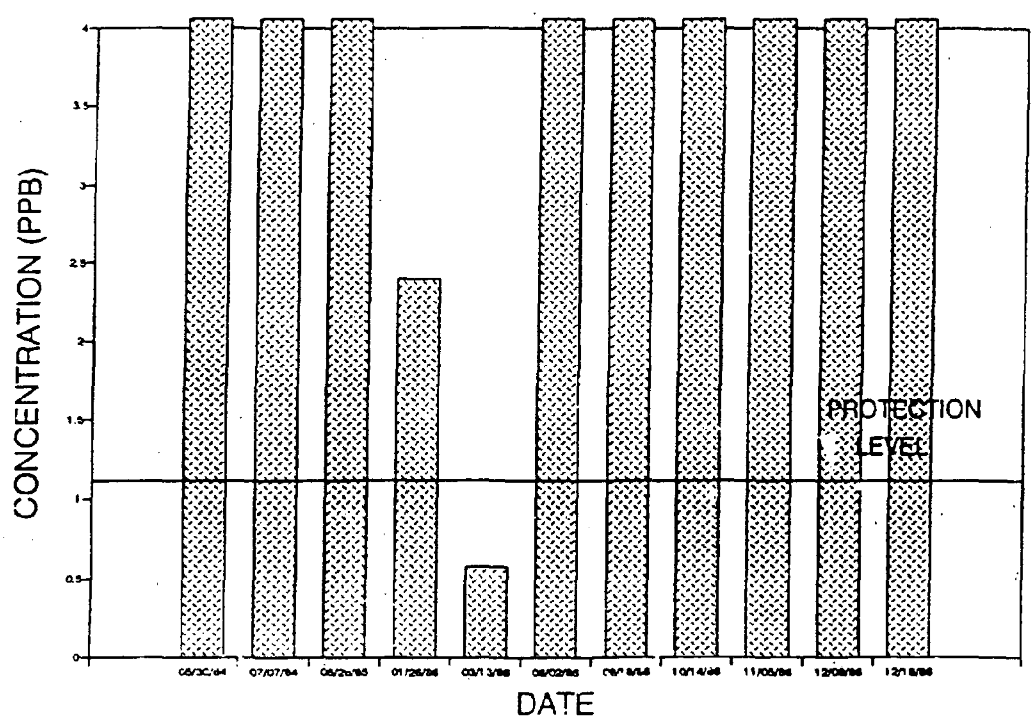
MANEB AQUATIC PROTECTION LEVEL = 1.10 PPB

CONCENTRATION OF MANEB IN RUNOFF ENTERING PONDS

POND 5



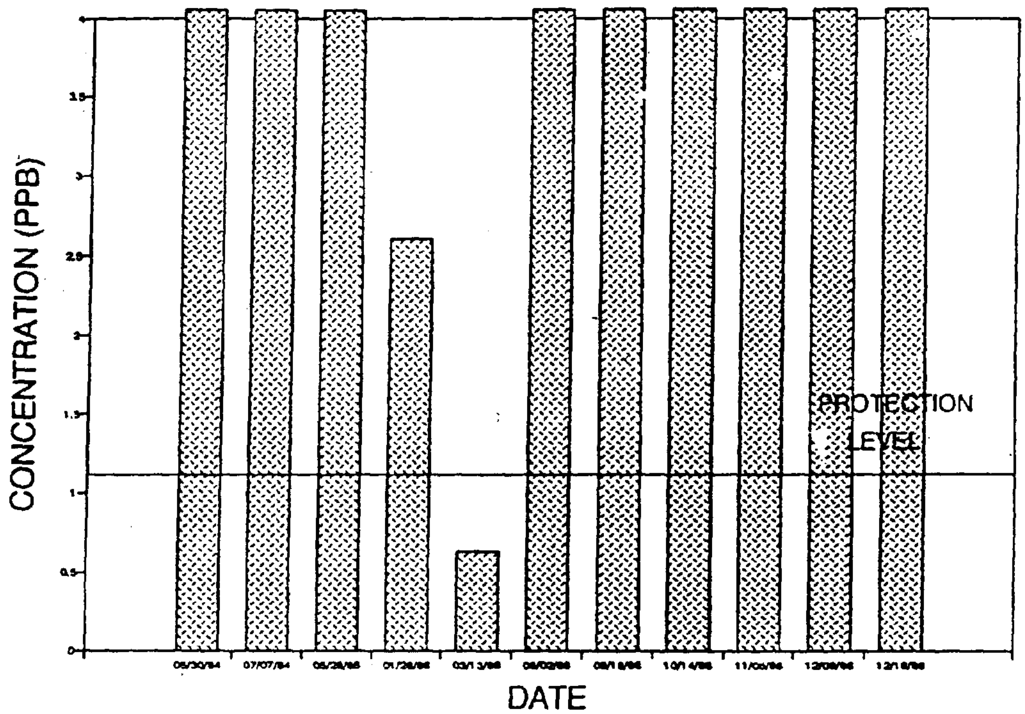
POND 6



MANEB AQUATIC PROTECTION LEVEL = 1.10 PPB

CONCENTRATION OF MANEB IN RUNOFF ENTERING PONDS

POND 7



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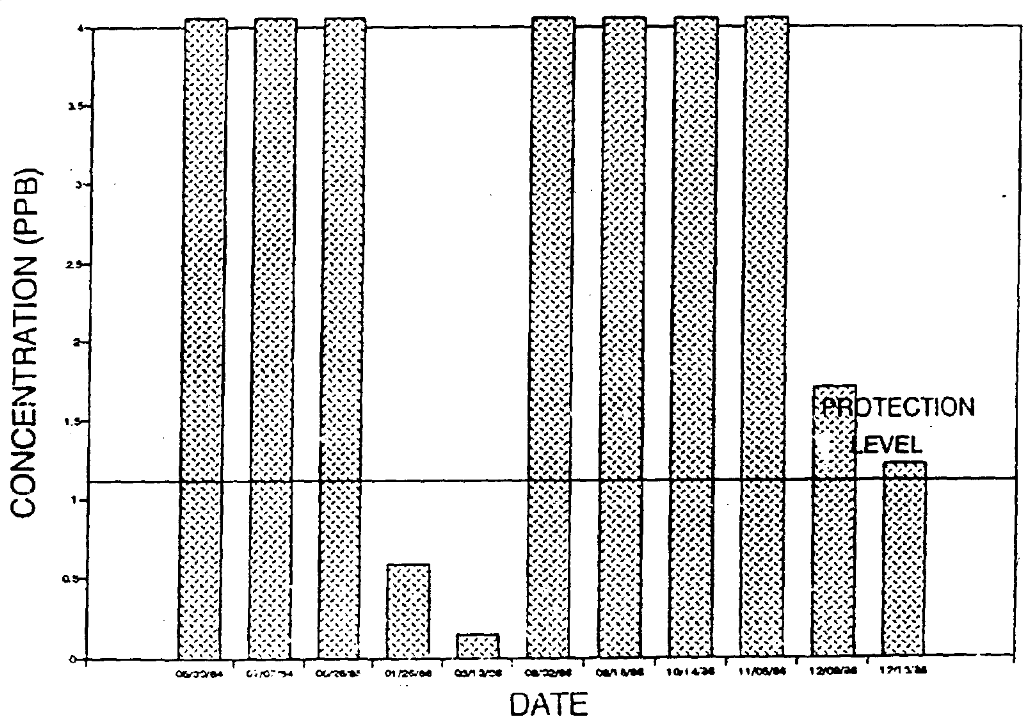
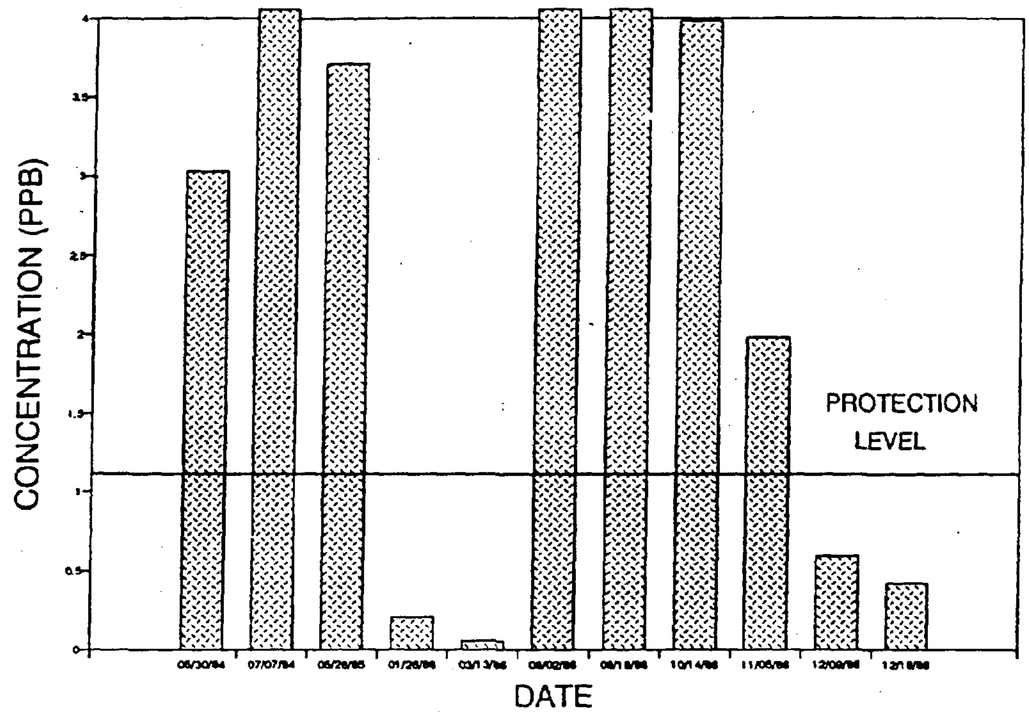


MANEB AQUATIC PROTECTION LEVEL = 1.10 PPB

CONCENTRATION OF MANEB IN RUNOFF ENTERING PONDS

POND 9



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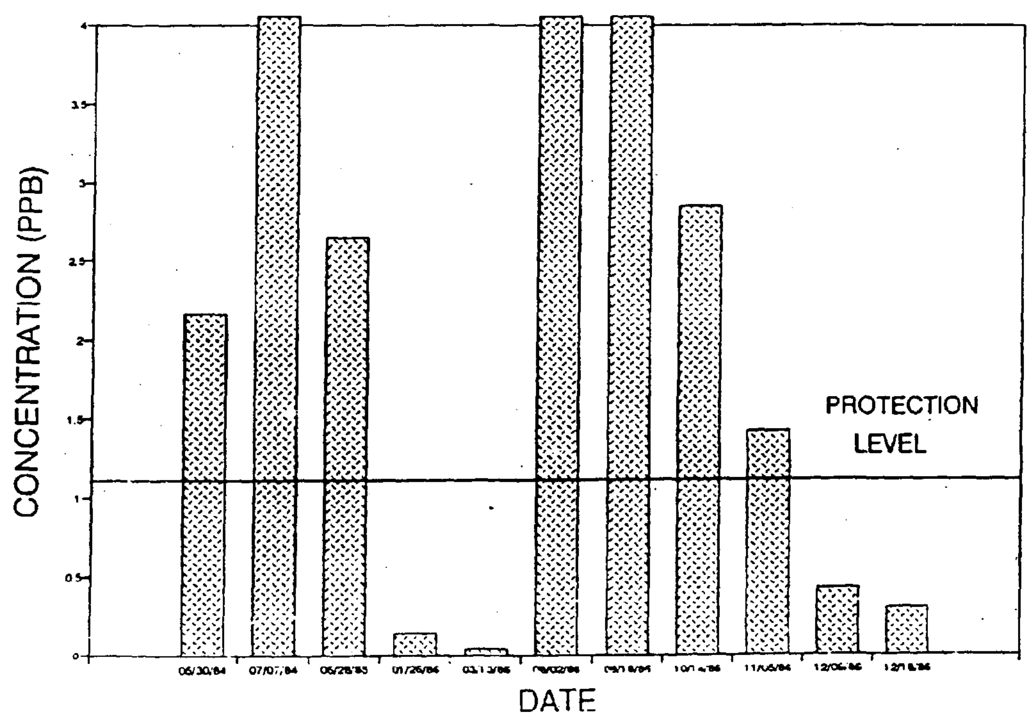
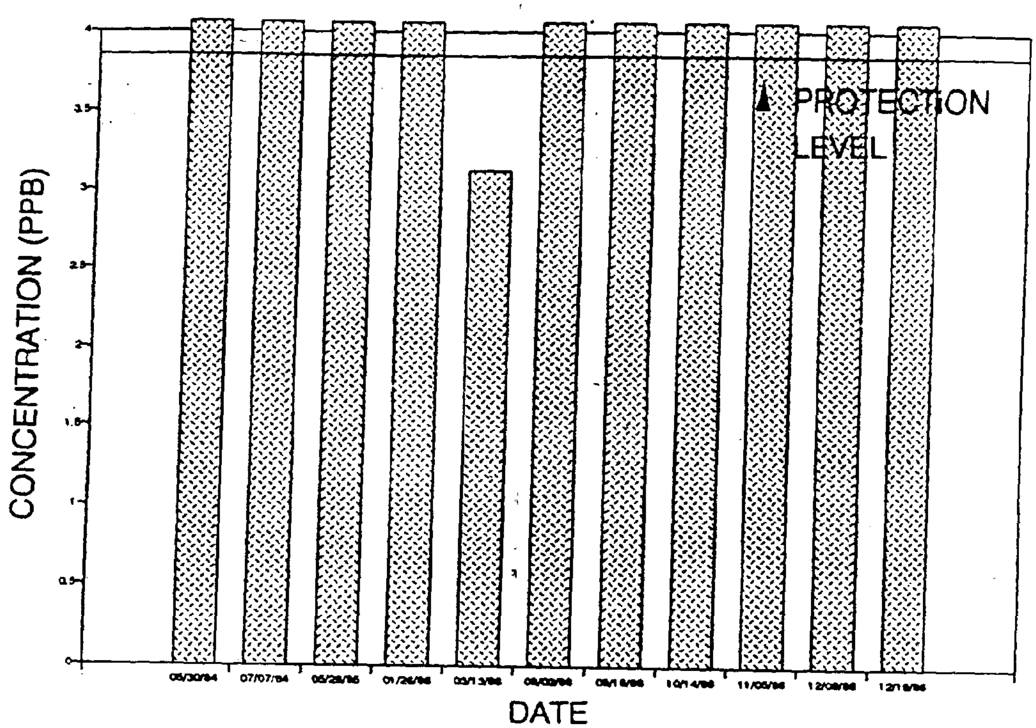


MANEB AQUATIC PROTECTION LEVEL = 1.10 PPB

CONCENTRATION OF BENSULIDE IN RUNOFF ENTERING PONDS

POND 1



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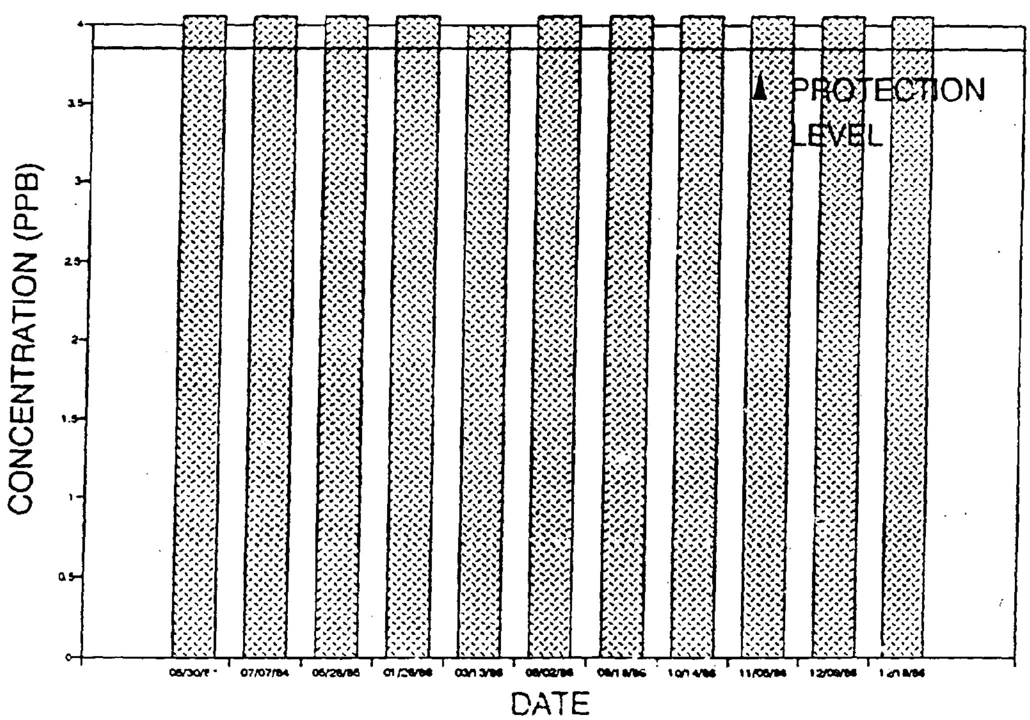
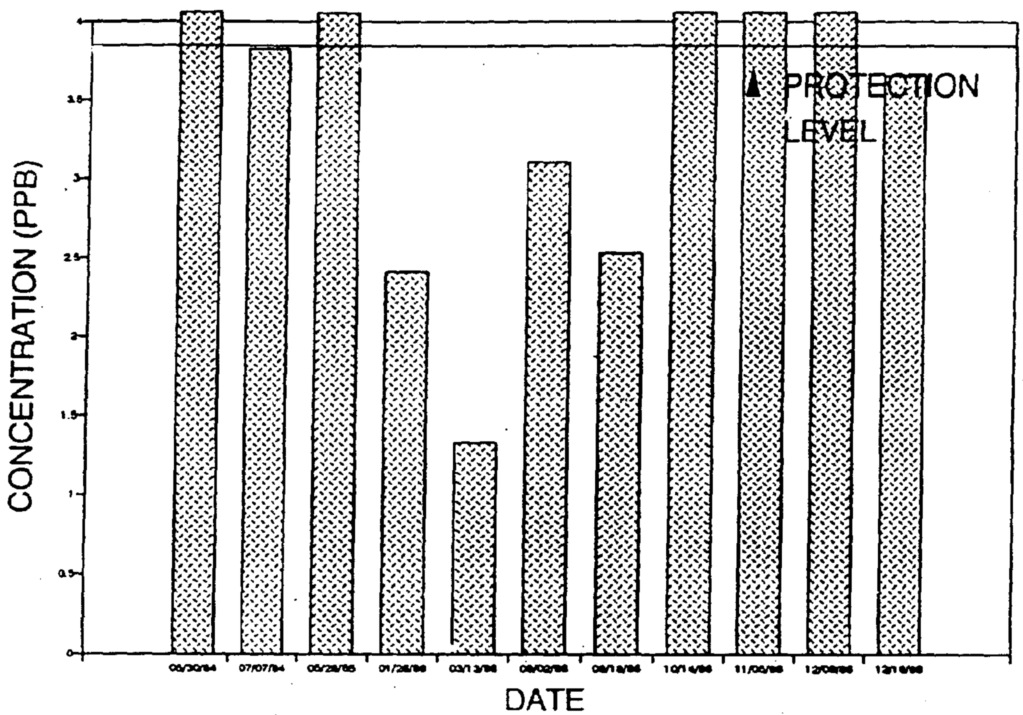


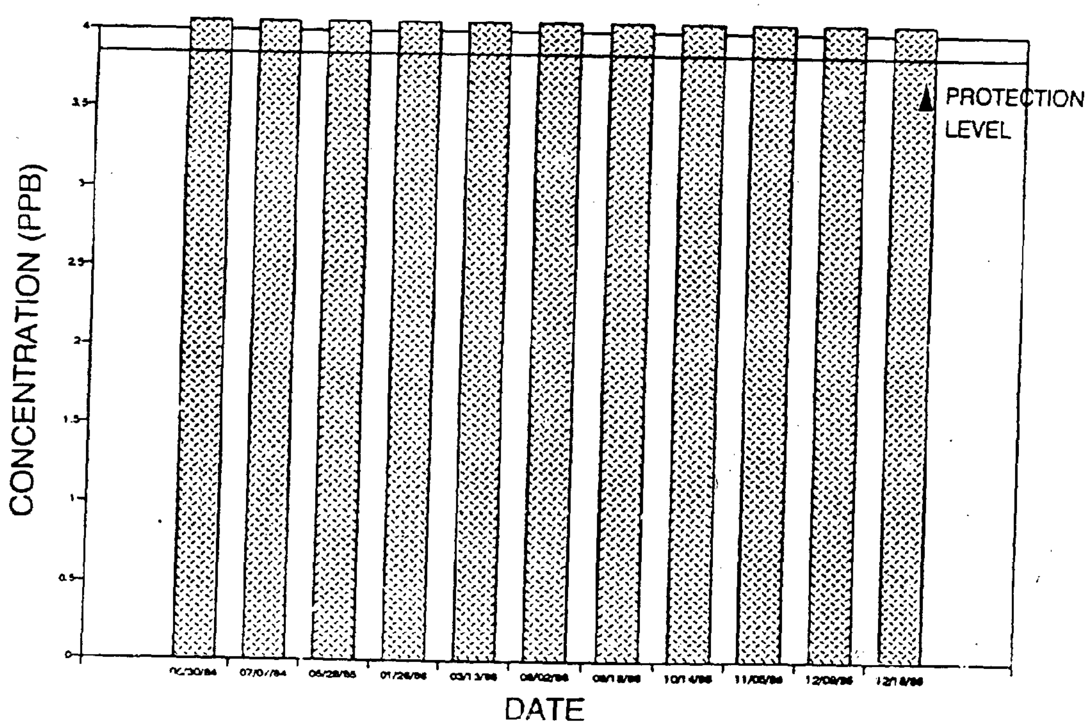
BENSULIDE AQUATIC PROTECTION LEVEL = 3.79 PPB

CONCENTRATION OF BENSULIDE IN RUNOFF ENTERING PONDS

POND 3



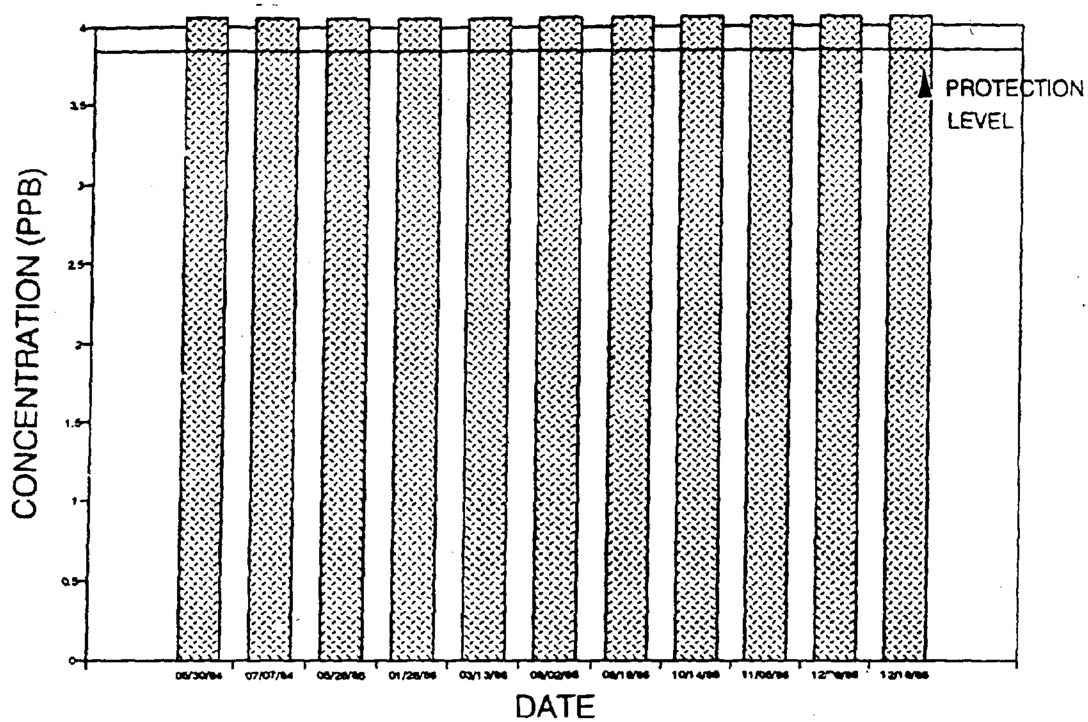
POND 4



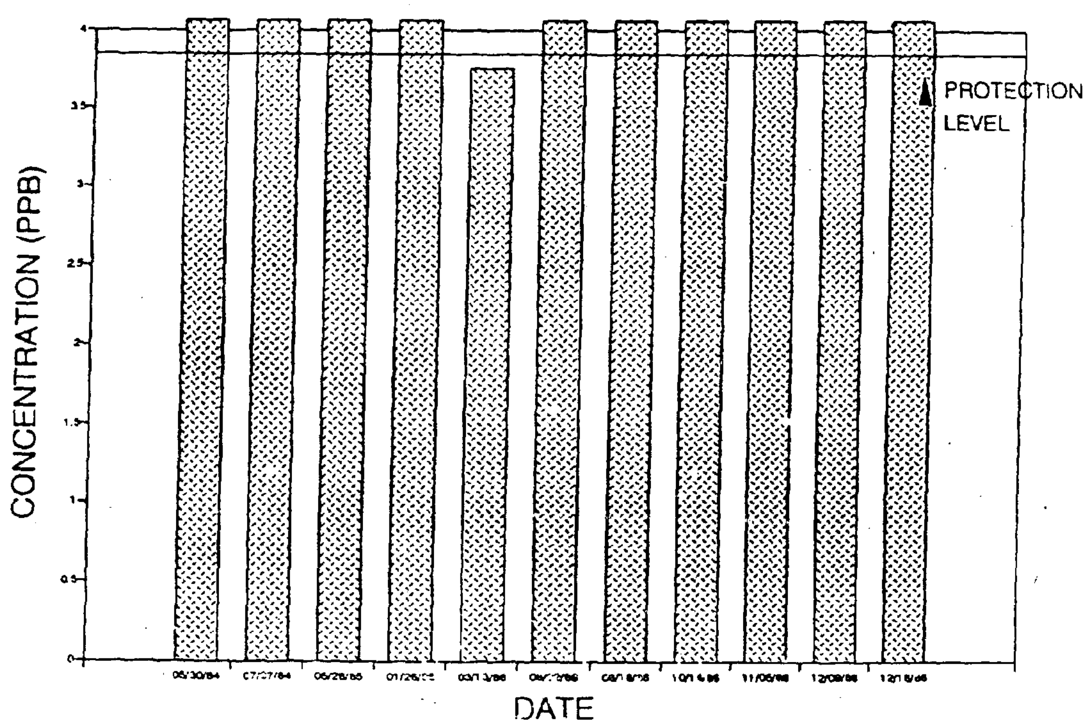
BENSULIDE AQUATIC PROTECTION LEVEL = 3.79 PPB

CONCENTRATION OF BENSULIDE IN RUNOFF ENTERING PONDS

POND 5



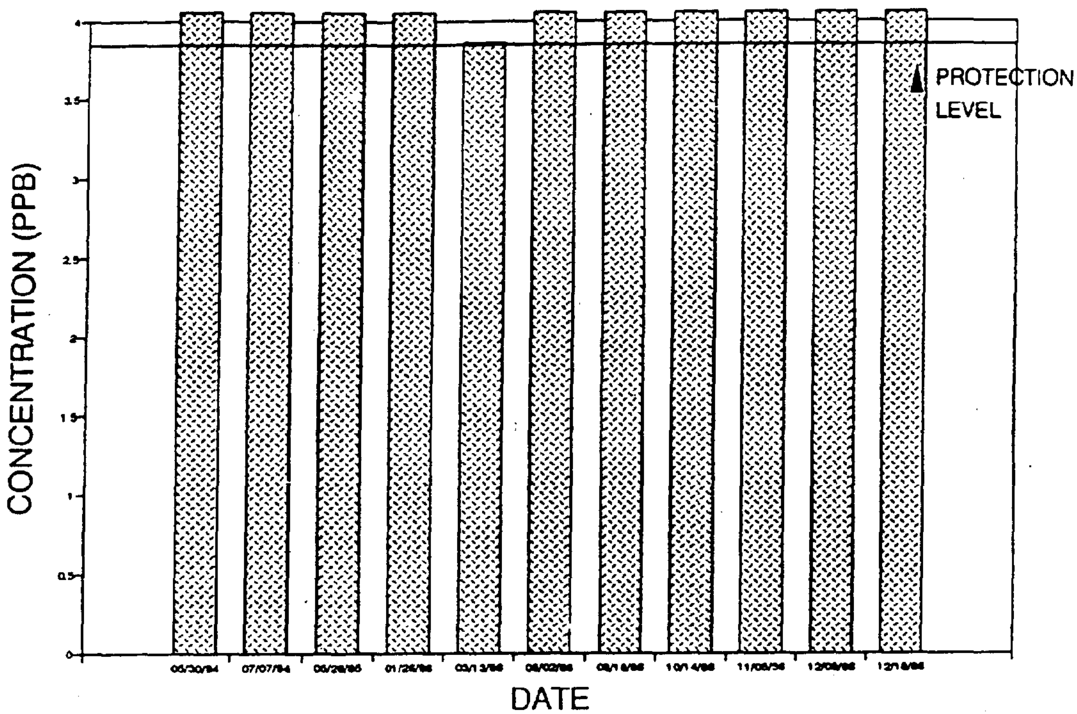
POND 6



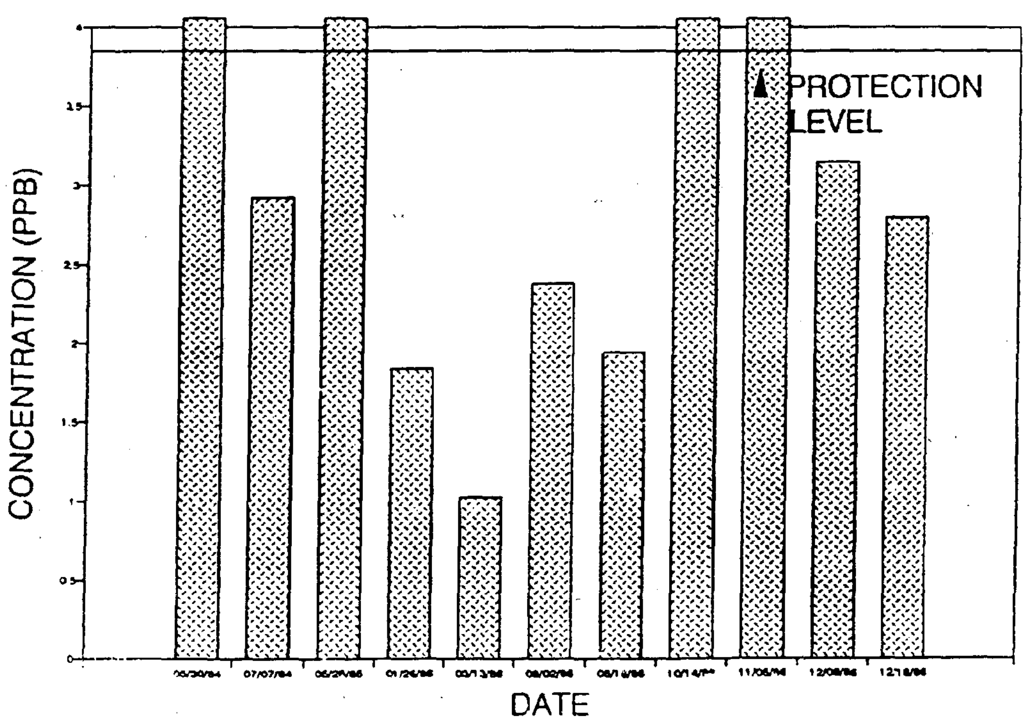
BENSULIDE AQUATIC PROTECTION LEVEL = 3.79 PPB

CONCENTRATION OF BENSULIDE IN RUNOFF ENTERING PONDS

POND 7



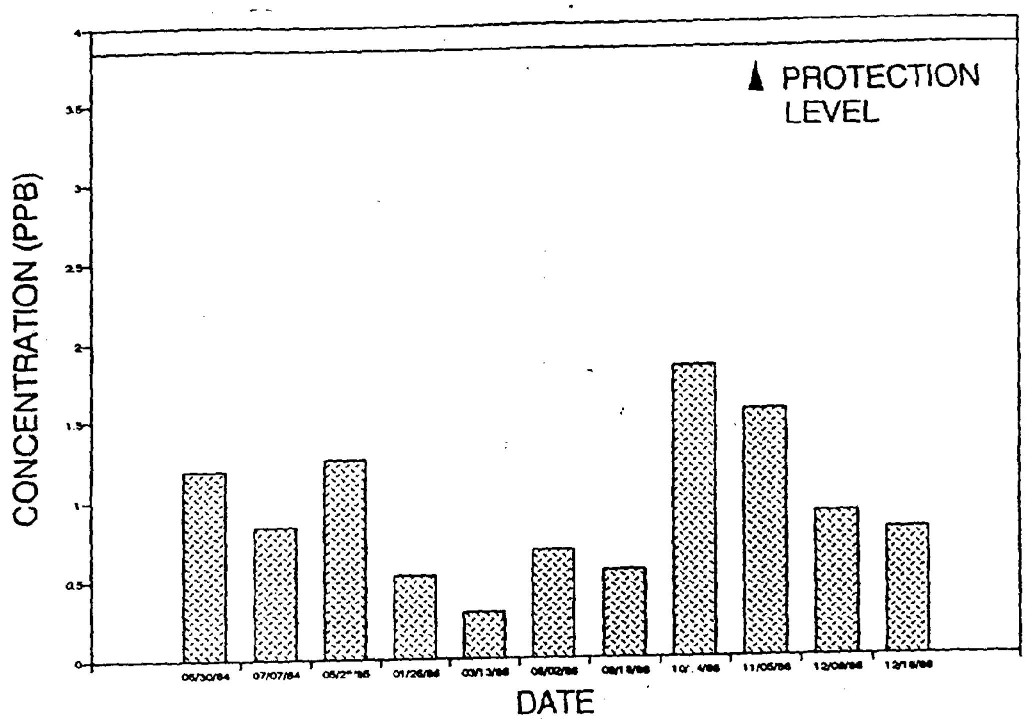
POND 8



BENSULIDE AQUATIC PROTECTION LEVEL = 3.79 PPB

CONCENTRATION OF BENSULIDE IN RUNOFF ENTERING PONDS

POND 9



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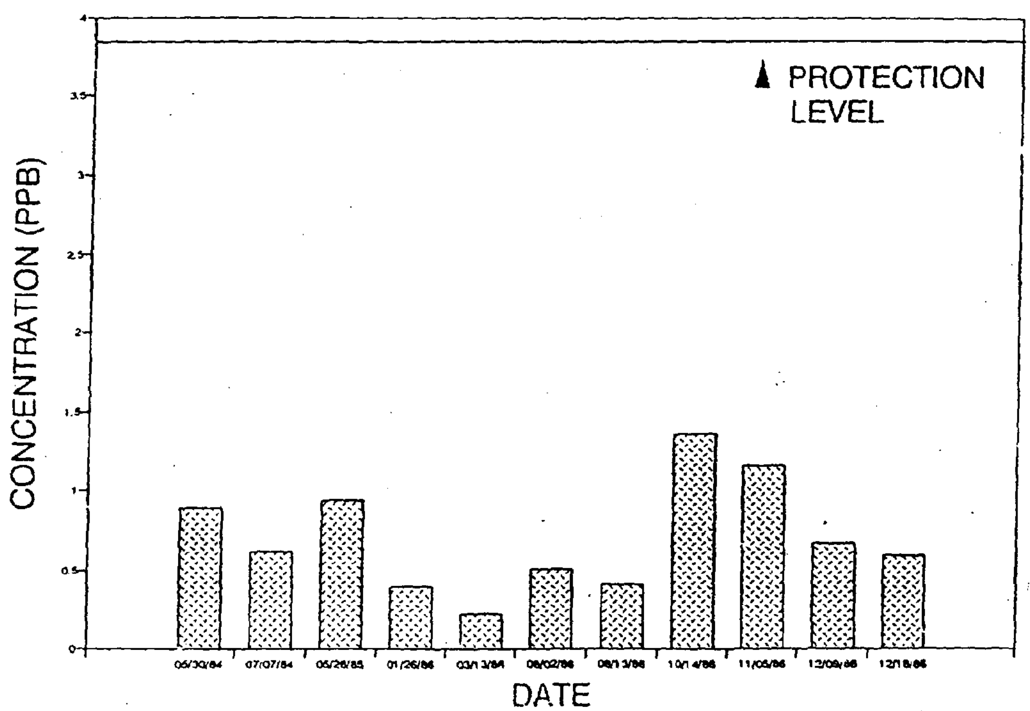

BENSULIDE AQUATIC PROTECTION LEVEL = 3.79 PPB

Appendix B.

DATA INPUT SOURCES for PRZM Model

ITEM	SOURCE
Pan Factor	PRZM Manual, p.40
Snow Factor	N/A
Minimum evaporation extraction depth	PRZM Manual, p.42
Avg. daily hours of light	PRZM Manual, p.43
Maximum active root depth	
Maximum areal coverage of crop	estimated
Runoff curve number	EPA
Depth of soil core	Atlantic County SCS
Number of soil compartments	Arbitrarily Chosen
Soil Bulk density	Atlantic County SCS
Number of soil horizons	Atlantic County SCS
Soil horizon thickness	Atlantic County SCS
Hydrodynamic dispersion	PRZM Manual, p. 76
Initial soil water content	EPA
Field capacity soil water content	EPA
Wilting point soil water content of horizon	EPA
Sorption partition coefficient for soil horizon/pesticide combination	EPA
Organic carbon content of soil horizon	Atlantic County SCS

	Chlorpyrifos	Bensulide	Benomyl
Half Life in Soil	SWRRBWQ, APP. 5	BC	SWRRBWQ, APP. V
Kow	PRZM, p. 72	BC	SWRRBWQ, APP. V
Soil Decay Rate	Calculated	Calculated	Calculated
Foliar Washoff	SWRRBWQ, APP. V	N/A	SWRRBWQ, APP. V
Plant uptake efficiency	Calculated	Calculated	Calculated
Plant Decay Rate	Calculated	N/A	Calculated
Half Life on Plant	SWRRBWQ, APP. V	N/A	SWRRBWQ, APP. V

	Maneb	Metalaxyl
Half Life in Soil	SWRRBWQ, APP. V	SWRRBWQ, APP. V
Kow	OL	Calculated
Soil Decay Rate	Calculated	Calculated
Foliar Washoff	SWRRBWQ, APP. V	SWRRBWQ, APP. V
Plant uptake efficiency	Calculated	Calculated
Plant Decay Rate	Calculated	Calculated
Half Life on Plant	SWRRBWQ, APP. V	SWRRBWQ, APP. V
Koc		SWRRBWQ, APP. V

SWRRBWQ = Simulator for Water Resources in Rural Basins-Water Quality, 2/6/91
BC = British Crop Protection Council, 9th Ed.
PRZM = Pesticide Root Zone Model, Release 1
OL = EPA Environmental Fate Database, 1990

CALCULATIONS

Plant Decay Rate = .693/half life days
Soil Decay Rate = .693/half life days
Plant Uptake = 0.784 exp - [(log Kow - 1.78)$_2$/2.44]
Efficiency Factor PRZM p. 75

Appendix B.

Reference Articles for Fate and Ground Water Monitoring Study for Pesticides and Nitrates

A Ground Water Monitoring Study for Pesticides and Nitrates Associated with Golf Courses on Cape Cod

by Stuart Z. Cohen, Susan Nickerson, Robert Maxey, Aubry Dupuy Jr., and Joseph A. Senita

Abstract

Scientists and regulators in the United States began emphasizing the study of pesticides in ground water in 1979 and 1980. The scientific community began to emphasize the study of nitrates in ground water as a result of fertilization in the mid to late 1970s. By the mid 1980s, tens of thousands of wells were found to contain elevated nitrate concentrations and detectable concentrations of pesticides. Few, if any, of the data were collected from wells associated with the nation's 13,000 golf courses.

Golf is popular on Cape Cod, an area that depends on a hydrogeologically vulnerable aquifer system as its principal source of drinking water. Pesticides and fertilizers are applied to golf courses, often at high rates on greens and tees. Therefore the EPA, the Barnstable County government, and several local golf course superintendents collaborated on a study of the impact of golf course turf management on ground water quality.

Nineteen monitoring wells were installed upgradient and in greens, tees, and fairways on four golf courses. Selected soil core samples were collected and analyzed. Four to six rounds of ground water samples were collected over one and a half years and analyzed for 17 pesticides and related chemicals; nitrate-N samples were collected at least monthly. Seven of the 17 chemicals were never detected. The most frequently detected chemical — dichlorobenzoic acid — probably had been an impurity in herbicide formulations. Chlordane was detected in several wells at concentrations exceeding the health advisory level, perhaps due either to repeated heavy applications coupled with preferential flow of the bound/particulate phase and/or cross contamination during well installation. The results show no cause for concern about use of these currently registered pesticides.

Nitrate-N concentrations were generally below the 10 ppm federal MCL, with some exceptions. Overall, nitrate-N concentrations decreased in response to lower application rates and use of slow-release fertilizer formulations.

Introduction and Background

Scientists and regulators in the United States began to emphasize the study of pesticides in ground water in 1979 and 1980 following detections of three pesticides. The nematicide 1,2-dibromochloropropane (DBCP) was found in the ground water of California, Arizona, South Carolina, and Maryland, and the insecticide/nematicide aldicarb (Temik) was detected in the ground water of New York and Wisconsin (Zaki et al. 1982, Cohen et al. 1984(a), Holden 1986, Lorber et al. 1989). Atrazine was also found in ground water during this time period (Spalding et al. 1980, Wehtje et al. 1981). EPA has implemented or proposed several regulatory actions as a result of these findings (U.S. EPA 1979, U.S. EPA 1983, U.S. EPA 1987(a), U.S. EPA 1988(a)).

The scientific community began to emphasize the study of nitrates in ground water as a result of fertilization in the mid to late 1970s (e.g., Olson et al. 1973, Hallberg 1986).

By the mid 1980s there had been extensive detections of pesticides and nitrates in ground water in many agricultural areas (USGS 1984, Cohen et al. 1986, Hallberg 1986, U.S. EPA 1988(b)). However, few if any of the data were collected from wells associated with the nation's 13,000 golf courses.

Rates of pesticide application to golf course greens and tees are usually much greater than analogous rates for farmland, but the greens and tees usually cover less than 3 percent of the total golf course (GCSAA/NGF 1985).

Golfing is a popular sport on Cape Cod, and golf courses are key factors in the local economy. Most of Cape Cod is underlain by a sole source aquifer, which supplies most of the area's drinking water (U.S. EPA 1982(a), Guswa and LeBlanc 1985). Cape Cod's hydrogeology is characterized by a shallow, unconfined, highly transmissive aquifer, high recharge, and sandy soils (Guswa and LeBlanc 1985). Consequently, local citizens and town officials began questioning whether new golf courses could be constructed without impacting ground water quality. Initially, these questions were evaluated by "paper" risk assessments involving environmental fate, toxicity, and Pesticide Root Zone Model assessments (Cohen 1984, Severn 1986). These EPA assessments generally concluded that good science could be used to select turf pesticides that could be applied without adversely impacting ground water. However, it was recognized that these modeling assessments were educated guesses that could be verified only with good monitoring data.

In addition, the Cape Cod Planning and Economic Development Commission (CCPEDC) had established a nitrate-N planning guideline of 5 ppm within zones of contribution to public supply wells to assure compliance with the 10 ppm federal MCL (CCPEDC 1978). Consequently, CCPEDC and EPA decided to conduct a ground water monitoring study of selected golf courses on Cape Cod.

Regional Hydrogeology

Cape Cod is comprised of unconsolidated glacial sediments that overlie bedrock. The bedrock surface dips eastward and ranges in depth from 80 feet below sea level at the Cape Cod canal to greater than 900 feet at Provincetown (Guswa 1985). The glacial sediments were deposited during the Pleistocene epoch as thrust moraines and outwash plains.

A number of spits and tombolos formed during the Holocene bound Cape Cod Bay, the Atlantic Ocean, and Nantucket Sound. A generalized map is shown in Figure 1. The Sandwich and Buzzards Bay moraines consist of sandy till mixed with stratified sand and gravel. Outwash plain sediments generally consist of stratified sand and gravel with local silt and clay layers. Eastern outwash plain sediments are mixed with till and ice contact sediments. Generally, sediments become finer grained with depth and distance from the moraines. The topography is marked by numerous kettles and kames. The outwash plains are cut by many stream valleys, which are usually dry (except where tidally influenced) due to the permeable nature of the underlying sand and gravel (Oldale 1981).

Six fresh ground water flow systems constitute the Cape Cod aquifer and are commonly referred to as lenses (Guswa 1985). Two of the lenses occupy upper Cape Cod, where the four golf courses in this study are located (Figure 1). The two lenses are separated by Bass River. Ground water in both systems flows radially from inland recharge areas to surface water discharge areas. Precipitation is the only source of fresh water recharge.

Annual ground water recharge is approximately 20 inches on Cape Cod (using the assumption presented by LeBlanc et al. 1986, that 45 percent of the average annual precipitation recharges the aquifer). Average annual precipitation on Cape Cod is approximately 44.3±2.2 inches. This average was derived from data from 15 coastal weather stations in Massachusetts during the period 1941 to 1970 (NOAA 1978). Also included were data from the station at Hyannis for the period 1985 through 1987. The Hyannis average and the NOAA average were not significantly different. These data indicate that quantities of precipitation are similar throughout upper Cape Cod. Recharge probably approaches 30 inches beneath the golf courses because of irrigation (approximately 20 in/year, according to the golf course superintendent at Hyannisport).

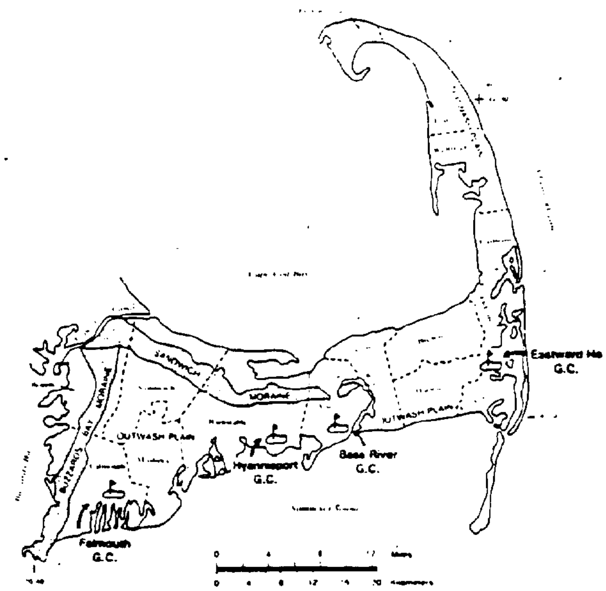

Figure 1. Golf course locations and physical features of Cape Cod (adapted from USGS 1985).

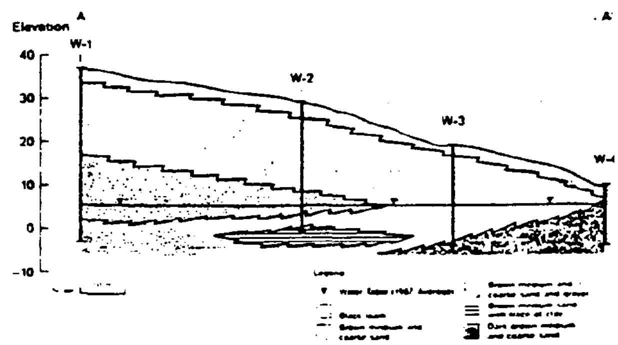

Figure 2. Bass River Golf Course geologic cross section.

The fresh/saline ground water transition zone is approximately 200 feet below the inland ground surface. The transition zone becomes shallower toward the shore. Most shallow ground water on Cape Cod occurs under unconfined conditions. Along the Outer Cape it occurs in lenses bounded by saline water (LeBlanc et al. 1986).

Site Descriptions and Hydrogeology

Bass River Golf Course

The Bass River Golf Course is situated on the west bank of Bass River, north of South Yarmouth, in the Harwich outwash plain. Sediments here consist of sand and gravel, which are mixed with clay in some places. A cross section of the study area is shown in Figure 2. Monitoring wells 5 and 6 are upgradient of the site followed by wells 1, 2, and 3. Monitoring well 4 is the most downgradient well.

Depth to ground water, as measured at the six monitoring wells, ranges from 6.45 feet to 35.37 feet below ground surface (Table 1). Elevations above sea level range from 4.72 feet to 6.92 feet as calculated from the overall depth to ground water. Potentiometric surface data recorded from the wells since 1984 indicate that ground water flow is generally to the southeast, toward Bass

TABLE 1
Monitoring Well Construction Summary*

Bass River Golf Course

	Well #1	Well #2	Well #3	Well #4	Well #5	Well #6
Location	Fairway #9	Green #10	Green #10 and Tee #11	Tee #11	Background	New background
Depth of Well	36.55 ft	29.45 ft	19.65 ft	11.50 ft	41.00 ft	40 ft
Length of Screen	3 ft—PVC	3 ft—PVC	3 ft—PVC	3 ft—PVC	3 ft—PVC	5 ft—Teflon®
Construction Method	PVC riser, glued joints	PVC riser, glued joints	PVC riser, glued joints	PVC riser, glued joints	PVC riser, glued joints	PVC riser, threaded joints
Drilling Technique	Drive and wash	Drive and wash	Drive and wash	Drive and wash	Drive and wash	Hollow-stem auger
Mean Depth to Water	32.17	24.80	14.64	6.45	35.37	25.56

* Wells 1-5 were installed previously for a related study.

Falmouth Country Club

	Well #1	Well #2	Well #3	Well #4
Location	Tee #18	Background	Green #17	New fairway well
Depth of Well	45.00 ft	40.00 ft	40.00 ft	40.00 ft
Length of Screen	5 ft—Teflon®	5 ft—Teflon	5 ft—Teflon	5 ft—Teflon
Construction Method	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints
Drilling Technique	Drive and wash	Drive and wash	Drive and wash	Hollow-stem auger
Mean Depth to Water	35.53	36.30	35.63	34.71

Eastward Ho! Country Club

	Well #1	Well #2	Well #3	Well #4
Location	Fairway #6	Background	Green #6	Tee #7
Depth of Well	15.00 ft	65.00 ft	9.00 ft	13.00 ft
Length of Screen	5 ft—Teflon®	5 ft—Teflon	5 ft—Teflon	5 ft—Teflon
Construction Method	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints
Drilling Technique	Drive and wash	Drive and wash	Drive and wash	Drive and wash
Mean Depth to Water	8.08	56.19	6.00	5.28

Hyannisport Country Club

	Well #1	Well #2	Well #3	Well #4	Well #5
Location	Green #2	Tee #16	Fairway #2	Background	New green well
Depth of Well	22.00 ft	15.00 ft	15.00 ft	27.50 ft	15.00 ft
Length of Screen	5 ft—Teflon®	5 ft—Teflon	5 ft—Teflon	5 ft—Teflon	5 ft—Teflon
Construction Method	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints	PVC riser, threaded joints
Drilling Technique	Drive and wash	Drive and wash	Drive and wash	Drive and wash	Hollow-stem auger
Mean Depth to Water	11.18	8.64	11.76	23.71	9.74

River, at a gradient of 0.001 (Table 2). Aquifer characteristic data generated by Guswa (1985) are presented in Table 2.

Falmouth Golf Course

The Falmouth Golf Course is located approximately 1 mile north of the village of East Falmouth. Cranberry bogs bound the property on the west. Sediments beneat this golf course belong to the Mashpee pitted outwas plain. Well logs (Figure 3) reveal that fine-to-coarse san and gravel underlie this site to -12.62 feet (MSL). Groun water occurs in the sandy gravel at mean depths rangin from 34.97 feet to 36.30 feet and elevations of 14.47 t 15.36 feet above sea level. Monitoring well 2 is the mos

TABLE 2
Aquifer Characteristics

	Bass River	Falmouth	Eastward Ho!	Hyannisport
Horizontal Hydraulic Conductivity (K, ft/day)*	250	150	225	250
Ratio of Horizontal to Vertical K*	10:1	10:1	10:1	10:1
Hydraulic Gradient (i)	0.001	0.002	0.050⁺	0.001⁺
Ground Water Velocity (V, ft/day)**	1.1	1.2	45	1.0

* Guswa 1986.

** Estimated velocity calculated using V = Ki/n, where n is porosity value for sand and gravel (Heath 1983). Hydraulic gradient determined from measure water table elevations in wells

⁺ This is gradient beneath green, tee, and fairway well. Background well is not included because it is not along same flow path.

upgradient well, followed by wells 4, 3, and 1. Monitoring well 4 is the most downgradient well. Ground water flow is north to south. The hydraulic gradient (Table 2) is 0.002, based on data from all five on-site wells. Ground water velocity is estimated to be 1.3 ft/day using the equation shown in Table 2.

Eastward Ho! Golf Course

Eastward Ho! Golf Course is located on the north side of Nickerson Neck. The course is bounded on the north by Pleasant Bay. Sediments beneath this golf course are part of the Harwich outwash plain. The plain also contains more recent beach sediments. Drilling logs reveal that the sediments consist of sand with some gravel. A clay layer was encountered at elevations of 5 feet to 58 feet. The elevation of the sand was approximately -10 feet MSL (Figure 3). Mean depth to ground water ranged from 56.19 feet at the background well to 5.28 feet at the tee well (Table 1). Mean water table elevations range from 1.44 feet MSL to 3.63 feet MSL (this does not include the background well elevation, because it was not surveyed). Ground water flow direction at the background well is to the northwest (based upon surface topography). Flow direction is to the northeast beneath the eastern portion, where the tee, green, and fairway wells are located. Ground water flows toward Pleasant Bay, which is within 20 feet of the course.

The ground water gradient (Table 2) is estimated to be 0.05 feet beneath the northeastern portion of the course. Ground water velocity is estimated to be 45 ft/day, assuming a formation porosity of 25 percent for the sandy aquifer (Heath 1984). Monitoring well 1 is the most upgradient well followed by wells 4 and 3. Monitoring well 2 is not within the same flow regime as the others but it is upgradient from areas of pesticide application.

Hyannisport Golf Course

Hyannisport Golf Course is located on the eastern shore of Centerville Harbor on Nantucket Sound. The sediments beneath this course are part of the Barnstable outwash plain and are predominantly fine to coarse sand, to at least an elevation of -10 feet MSL. Monitoring wells 1 and 5 are the most upgradient wells followed by wells 2 and 3. Monitoring well 4 is not within the same flow regime as the others but it is upgradient from areas

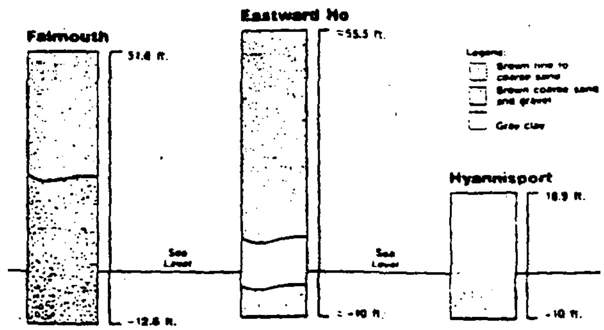

Figure 3. General geologic logs.

of pesticide application.

Ground water flow is to the south-southwest, beneath the portion of the golf course where the green, tee, and fairway wells are located. Ground water flow is probably to the southeast at the background well, based on topography. This could not be measured because the background well does not lie within the same flow path as the three other wells. The gradient beneath the tee, green, and fairway wells is estimated to be 0.001 (Table 2). Ground water velocity beneath the course in this area is estimated to be 1 ft/day, assuming a sand porosity of 25 percent (Heath 1983). The golf course is situated within a probable zone of contribution to a nearby public well.

Study Design

Golf Course Selection

Initially, the objective was to estimate the extent of occurrence of pesticides and nitrates in the surficial aquifer as a result of their application to all 30 golf courses on Cape Cod. Hydrogeologic vulnerability and pesticide usage were to be used as design parameters. Thus it was decided to use stratified random sampling (Snedecor and Cochran 1980, Cohen et al. 1986) to select the golf courses for study. However, there were funds to study only four golf courses, and a properly conducted stratified random study, with conclusions applicable to all golf courses on the Cape, would have required more than four. Therefore it was decided to conduct a worst-case assessment first followed by a more comprehensive study if indicated by the results of the first study.

The Cape's seven nine-hole golf courses were eliminated from the potential sampling universe because it was believed that their turf management practices might not be representative of most golf courses. The remaining golf courses were evaluated according to the following design criteria:

- Site stratigraphy/hydrogeologic vulnerability. Higher risk ratings were assigned to golf courses in glacial outwash plains with sandy soils. Lower risk ratings were assigned to golf courses overlying moraine deposits, which may contain silt, clay, or other relatively impervious deposits.
- Pesticide and fertilizer usage. Subjective rankings were based on the amounts of pesticides and nitrogen fertilizers applied. Information was obtained from golf course records and interviews with golf course superintendents.
- Golf course age. Golf courses more than 30 years old were assigned a higher risk rating due to the increased time available for pesticides to migrate to ground water and the increased likelihood that older, riskier pesticides would have been applied to the golf courses.

Seven golf courses were ranked high in all three potential risk categories. The original plan was to randomly sample four golf courses from the high-potential-risk list so that statistically valid inferences could be extrapolated to all golf courses in that risk category. However, only four of the seven golf course personnel agreed to participate in the study. Thus the golf courses included in the study are Falmouth Country Club, Hyannisport Club, Eastward Ho! Golf Club, and Bass River Golf Club. Their locations are depicted in Figure 1.

Chemical Selection

A list of pesticides commonly applied to golf course turf on Cape Cod was developed and evaluated according to three criteria:

- Environmental fate—mobility and persistence
- Toxicity—drinking water health guidance levels
- Analytical chemistry—methods and detection limits.

Pesticide mobility and persistence were evaluated to ensure that pesticides with even a slight potential to leach to ground water (Cohen et al. 1984) would be included in the study. Health guidance levels (HGLs), which include HALs, MCLs, SNARLs, etc., were not available for most pesticides, so they were calculated according to the following formulas. HGLs for pesticides exhibiting threshold effects, i.e., toxic endpoints with a No Observable Effect Level, can be calculated as follows:

HGL = ADI x 70 kg/2L/day (for most toxic effects)

HGL = ADI x 10 kg/1L/day (for cholinesterase inhibitors)

where

ADI = acceptable daily intake in mg/kg/day
70 kg = adult body weight
10 kg = child body weight
2 L/day = standard water consumption factor for adults
1 L/day = standard water consumption factor for children.

For carcinogenic endpoints, the HGL was calculated from the carcinogenic potency factor (Q*) for a negligible risk standard—a 1×10^{-6} upper limit probability of cancer occurrence in a lifetime of exposure.

The list of organic chemical analytes, their common names, and their uses are contained in Table 3. HGLs are provided in the discussion section of this paper for pesticides that were detected.

One to four years of pesticide application data provided by the golf course superintendents are provided in Table 4. The reader is cautioned against extrapolating these data too far into the past. For example, chlordane use on turf was not allowed during this time period. Also, it is the first author's experience that, over a multiyear period, 2,4-D and mecoprop use might have been more widespread than it is today as indicated on this table. Nitrogen application data are contained in Table 5.

TABLE 3
Organic Analytes for the Cape Cod Golf Course Study

(Common Name/Trade Name)

Herbicides	Fungicides	Insecticides
dacthal/DCPA*	chlorothalonil/Daconil	chlorpyrifos/Dursban®
chlordane**	anilazine/Dyrene	trichloropyridinol
dicamba	iprodione/Chipco 26019	(Dursban metabolite)
mecoprop/MCPP		isofenphos/Oftanol
2,4-D		diazinon
2,4-dichlorobenzoic acid†		chlordane**
siduron/Tupersan		
pentachlorophenol/PCP††		

* Dacthal diacid metabolite included.
** Technical chlordane and heptachlor epoxide.
† Use unknown; suspected impurity.
†† Specific target pest unknown, but this wood preservative had been formulated as part of an herbicide mixture

TABLE 4
Pesticide Application Data* ‡

Pesticides	Bass River (AI) 1984	Bass River (AI) 1985	Bass River (AI) 1986	Bass River (AI) 1987	Falmouth (TP) 1986	Falmouth (TP) 1987	Hyannisport (AI) 1986	Hyannisport (AI) 1987	Eastward Ho (TP) 1986	Eastward Ho (A 19
							No Data			
dacthal										
diazinon	- -									
dicamba	0.06 gal	0.02 gal								
2,4-D	0.50 gal	0.13 gal							6.75 gal	1.77
anilazine					10.1 gal	18.1 gal			7.5 gal	
chlordane										
chlorothalonil	31.75 gal	15.6 gal	9.0 gal	4.04 gal	4.1 gal			3.64 gal	5.5 gal	8.08
chloropyrifos	41.0 lb				2.0 gal			2.20 gal		3.30
iprodione	69.2 lb	27.0 lb	5.1 gal	.98 gal				8.95 gal		9.40
isofenphos	55 gal	2.75 gal	1.5 gal	.55 gal	42.0 gal				6.2 gal	
mecoprop (MCPP)	0.27 gal	0.07 gal								
pentachlorophenol						5.34 gal				
siduron					9.38 gal			6.6 gal	32.0 lb	

* Pesticides on this table were analyzed for this study. This list does not include all the pesticides used on the golf courses.

AI—Active ingredient.

TP—Total product.

‡ Total areas of tees, fairways, and greens are as follows:
- Bass River – 45 acres
- Falmouth – 42 acres (including roughs)
- Hyannisport – 29.1 (including roughs)
- Eastward Ho! – 44.5 acres (including roughs).

TABLE 5
Average Nitrogen Applied per Year ($lb/1000\ ft^2$)

	Bass River			Falmouth			Hyannisport			Eastward Ho!		
	T	G	F	T	G	F	T	G	F	T	G	F
1987	2.0	4.0	2.0	3.0	4.0	2.0	3.1	4.0	1.1	1.7	1.7	NA
1986	2.1	4.8	1.9	2.0	6.2	2.0	3.0	3.5	3.2	4.0	5.0	2.6
1985	4.35	5.5	2.0	NA*	NA	NA	NA	NA	NA	2.6	1.2	2.0
1984	3.6	4.0	3.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
1983	1.0	5.25	3.5	NA	NA	NA	NA	NA	NA	NA	NA	NA

T = tee, G = green, F = fairway.

* No data available.

Monitoring Well Site Selection

Monitoring well site selection was performed in conjunction with the U.S. Geological Survey. Under an EPA/USGS cooperative agreement, CCPEDC staff and a hydrogeologist from the USGS Boston office reviewed each golf course for appropriate monitoring well locations. In each case, on-course wells were sited at a fairway, a green, and a tee so that variable management practices within each course could be evaluated. Wells were placed where the shallowest depths to ground water occurred and downgradient of the site of interest (tee or green) when the well could not be placed directly in the managed area. Upgradient background wells were sited in locations presumed to be unaffected by nearby sources of contamination, such as septic systems or road runoff. It was not possible to site the background well directly upgradient of the monitoring wells at the Hyannisport and Eastward Ho! golf courses.

Generally, wells were not placed in areas where surface runoff might collect. One exception was the green well at Eastward Ho! Country Club, which was at the base of a steep mound, on top of which was the green.

Methods

Monitoring Well Construction

Nineteen ground water monitoring wells were installed for this study. At each of the four golf courses participating in the study, wells were placed at one tee, one green, and one fairway, and one well was placed upgradient of all treated areas to establish background water quality conditions (Table 1). Sixteen of the wells were installed in 1985 using the drive-and-wash technique. Three additional wells were installed in 1987 using a hollow-stem auger, in response to concern that the drive-and-wash method may have caused cross contamination between surface soils and the aquifer. All of the wells are flush mounted and made of 2-inch PVC. The wells were screened a . or just below the water table. Equipment during drive-and-wash installation was cleaned with water between boreholes. Hollow-stem auger equipment was steam cleaned between holes.

A sand pack was placed 1 to 2 feet above the top of the screen, followed by a bentonite seal. Native soil was then backfilled into the annular space in wells completed by the drive-and-wash method. This was done contrary to the well construction protocol, but according to standard practice in that area, and may have caused cross contamination (see the discussion section). The wells were developed by bailer until the water was clear.

Ground Water Sampling

Each well was cleared of four times its volume prior to sample collection, based on guidelines developed by the National Water Well Association and the Massachusetts Department of Environmental Quality Engineering. Evacuation was accomplished by peristaltic pump where distances to ground water allowed. Otherwise wells were evacuated by bailing.

In the initial phase of the project, samples were collected using a Teflon® bailer, which was washed with hexane between each well, and rinsed three times with deionized water. Later in the study, after pesticides were detected in the wells, dedicated PVC bailers were assigned to each well that tested positive.

Water samples were placed in 1-liter amber glass bottles for pesticide analysis and 500mL glass jars for nitrogen. Samples were kept in sturdy plastic coolers with ice until repacked for shipping or delivered to the laboratory.

EPA-approved QA/QC procedures for sample integrity, including chain-of-custody protocol, were followed throughout the monitoring program.

Pesticide samples were collected quarterly over a one and a half year period beginning in April of 1986. Sampling was conducted in August of 1986 and 1987, one to two months after the usual application time of the more mobile herbicides—2,4-D, MCPP, and dicamba. This sampling schedule should have been adequate considering the likely time-of-travel of these solutes. Nitrate samples were collected semimonthly or monthly at all four courses over a two-year period beginning in January 1986.

Analytical Methods

All pesticide analyses were performed by EPA's Environmental Chemistry Laboratory (Office of Pesticide Programs) in Mississippi.

Organochlorine/Organophosphate (OC/OP)—Ground Water and Soil

The determination of the OC/OP components was based on U.S. EPA methods for ground water (U.S. EPA 1982(b), 1982(c)) and for soil samples (U.S. EPA 1980). Some modifications of these procedures were used; however, all analytical methods were validated in the lab prior to beginning analytical work.

The water samples were extracted with methylene chloride and were cleaned up on silica gel columns. The soil samples were extracted with acetone/hexane, followed by a two-stage cleanup on a Florisil® column followe[d by] a silica gel column.

Detection and quantitation of analytes were acc[om]plished by gas chromatography (GC) with a Hew[lett-]Packard 5710 GC (ground water) and a Hewlett-Pack[ard] 5730 GC (soil), both equipped with Ni-63 electron capt[ure] detectors (ECD). All samples were analyzed on [two] columns (6 foot x 4mm I.D.) consisting of 3 perc[ent] SP-2100 and 5 percent SP-2401 operated at 190 [C.] Approximately 20 percent of positive samples were a[na]lyzed on a third column (6 foot x 4mm I.D.) consistin[g of] 31 percent SP 2250 operated between 200 and 215 [C] depending on the analytes present.

Quantitation was done by comparing responses [of] analytes in the sample with responses of authentic, a[na]lytically pure external standards.

Iprodione was not analyzed for after the first rou[nd] due to the labor-intensive nature of this extraction [and] the total lack of detections for this pesticide in the f[irst] round.

Phenoxy/Phenol—Ground Water

The analysis of the chlorinated phenoxy/phenol a[na]lytes was based on validated modifications to U.S. E[PA] methodology (U.S. EPA 1982(d)).

The water was acidified and extracted with et[her,] hydrolyzed with base followed by ether wash, reacidi[fied] and extracted with ether, concentrated, methylated, [and] cleaned up on Florisil® and silica gel columns.

The GC analyses were performed on a Hewl[ett-]Packard 5710 equipped with Ni-63 ECD. All sam[ples] were analyzed on two columns (6 foot x 4mm I.[D.)] consisting of 3 percent SP-2100 operated at 165 C [and] 5 percent SP-2401 operated at 170 C. Approxima[tely] 20 percent of positive samples were analyzed on a th[ird] column (6 foot x 4mm I.D.) consisting of 5 perc[ent] SP-2250 operated at 190 C.

Quantitation was accomplished as in the OC[/OP] method.

Siduron—Ground Water

The analysis of siduron in the ground water samp[les] was based on U.S. EPA methods (U.S. EPA 1982(e) a[nd] U.S. EPA 1987(b)).

The pH of the water samples was adjusted to 7, a[nd] they were extracted with methylene chloride.

The siduron concentration was determined us[ing] high-pressure liquid chromatography (HPLC) usin[g a] Waters Model 840 HPLC System with a DuPont Zorb[ax] ODS (C-18, reverse phase) column operated at ro[om] temperature. An isocratic solvent system of water, a[ce]tonitrile, 45/55 with a flow rate of 1.0 mL/min and a [UV] detector (238 nm) were used.

Confirmational Analyses

Gas chromatography/mass spectrometric (GC/M[S]) analyses were performed on analytes detected with [a] Finnigan 5100 GC/MS System equipped with a 1[5 m] DB-5 capillary column (0.25mm I.D.) operated betwe[en] 60 and 220 C at 20 C/min.

Sample Containers, Shipment, and Storage

Water samples were collected in specially cleaned 1-liter amber Wheaton® bottles fitted with Teflon-lined lids. The bottles were washed with detergent and water, followed by rinsing and distilled water, acetone, and methylene chloride and were dried overnight in an oven at 350 C.

Soil samples were collected in quart Mason® jars cleaned as previously described for the water samples. These containers had Teflon-lined lids.

All samples were shipped under ice via "next-day delivery" from Cape Cod directly to the laboratory. The samples were kept refrigerated (4 C) and out of light at the laboratory until the time of analysis.

Quality Assurance/Quality Control

In general, quality assurance and quality control were maintained using established U.S. EPA methods (U.S. EPA 1976, U.S. EPA 1984, U.S. EPA 1986). Prior to the study, a Quality Assurance Project Plan (QAPP) was specifically written and approved for the analytical work associated with the project.

Detailed sample tracking documentation was used throughout the analyses, and all lab glassware and reagents were cleaned prior to use following U.S. EPA-approved procedures.

As part of the QAPP, a method validation study was done prior to analyzing samples to determine minimum detection limits (MDLs) and to determine the precision and accuracy of the method. Ten to 12 water/soil replicate samples, spiked at 2 x, 4 x, and 100 x MDLs for all analytes, were run for each method. The precision and accuracy data obtained during these studies were used to construct control charts, which were maintained throughout the analysis of field samples.

The field samples were analyzed in sets of no more than 15 total samples. Typical sets consisted of no more than 8 to 10 field samples, one field bank, one method blank, one duplicate sample, one standard reference spike control, and one cleanup control, when a method with cleanup was used.

To minimize any problems associated with long holding times, ECS expected to extract all samples within three weeks after arrival at the laboratory. This was the case with OC/OP ground water sample sets, with one exception—a 27-day holding time. There were three exceptions with the phenoxy/phenol ground water sample sets—two at 22 days and one at 30 days. The analytes of interest were considered stable once in their final extract. Final analyses were completed within two to five weeks after extraction.

The soil cores, taken in December 1985, were not shipped to ECS until September 1986. Prior to shipment, they had been stored in a freezer. They were stored continuously at 4 C, as described earlier, and were extracted in October and November of 1987. Analyses were completed over the period October 1987 through January 1988.

The standard reference spike consisted of spiking a water or soil matrix with analytes of interest and carrying this sample through the entire procedure. Recovery values obtained on these samples were plotted on control charts, which were maintained for all analyses, except for anilazine, which could not be accurately quantitated. Data on precision, expressed as standard deviation (SD) and relative standard deviation (RSD), and recovery, expressed as mean percent recovery, for the method obtained on these QC samples was calculated for the ground water samples. Recoveries (accuracy) averaged better than 70 percent for the majority of analytes, and precision, expressed as RSD, was, in general, below 20 percent for most analytes.

A method validation study for soil was used to construct the control chart limits. Recoveries averaged better than 70 percent for all analytes, and RSDs for all analytes were well below 10 percent.

Many of the samples in the study were run in duplicate, and several samples were run in replicate, that is, they were re-extracted at a later date. Precision data, expressed as relative percent difference (RPD), were calculated for the duplicates and replicates. RPD was calculated using the following:

$$RPD = \frac{|x_1 - x_2|}{\frac{(x_1 + x_2)}{2}} \times 100$$

where RPD is relative percent difference between duplicates

x_1 = concentration (ppb) of analyte in sample

x_2 = concentration (ppb) of analyte in duplicate sample

The mean RPDs for most analytes averaged less than 20 percent.

Surrogate standard spikes were used in each sample to assess matrix effects and mechanical losses of recoveries for the analytes in the OC/OP and phenoxy/phenol methods. Methyl parathion and p,p'-DDT were used for the former method, and 2,4,5-T for the latter. Predetermined recovery acceptance limits for these surrogates had to be obtained in order to have a valid analysis for each sample.

Analyte detection limits were significantly different than background noise, as all reported quantitative positives demonstrated a signal to noise ratio of at least 10:1 on the gas chromatograms. The linear operating ranges of GC detectors were determined prior to analysis and all analytical standard solutions were validated prior to use. The analytical purity of all standards was $>$ 98 percent.

Nitrate-N Analysis

Ground water samples were analyzed for nitrate-N by the Barnstable County Health and Environmental Department using the American Public Health Association (1985) Standard Method 418-A - UV Spectrophotometry.

Organic Matter Analysis

Organic matter content of the soil cores was analyzed by the University of Maryland Cooperative Extension Service's soil testing lab using the dichromate oxidation colorimetric method.

Results

Pesticide Analyses

Results of analyses of soil cores from three golf courses for eight pesticides are contained in Table 6. The soil cores were collected during well installation. Only technical chlordane—a mixture of several hepta-, octa-, and nonachlorinated compounds—and heptachlor epoxide were found. Heptachlor is a component of technical chlordane, and heptachlor epoxide is a weathered or oxidized form of heptachlor. Chlordane reportedly was used as a turf herbicide and insecticide from the 1950s to the 1970s. Soil cores were not collected from the Bass River golf course because most of the monitoring wells had been installed shortly before this study began.

Results of analyses of ground water for 17 pesticides and related compounds are contained in Table 7. Ten of the compounds were detected. In decreasing order of frequency of occurrence, they were (number of wells with detections in parentheses): 2,4-dichlorobenzoic acid (DCBA) (10); technical chlordane residues, including heptachlor epoxide residues (7); total dacthal residues, specifically the diacid metabolite (3); chlorothalonil (2), isofenphos (2), chlorpyrifos, including the pyridinol metabolite (2); dicamba (1); and 2,4-dichlorophenoxyacetic acid (2,4-D) (1). Generally, the highest concentrations were DCBA, followed by chlordane and the other pesticides. Most pesticide concentrations we less than 5 ppb. The toxicologic significance of the resu is discussed in the following text, as are trends in the da

For the sake of simplicity, only results of the 16 k study wells are presented in Table 7.

Nitrate-N Analyses

Results of analyses of nitrate-N are contained Table 8. Most samples contained detectab concentrations.

Discussion

Pesticides

Spatial Trends

Most findings of pesticides and related compounds ground water centered around the greens and tees. A eight green and tee wells had at least one detection duri the study, whereas only three fairway wells and tv background wells had detections. The difference is ev more apparent when one totals individual chemic detections for each well. Using this approach, the followi numbers are obtained: green wells-12 detections; t wells-12 detections; fairway wells-7 detections; bac ground wells-2 detections (both were DCBA, the appare herbicide impurity). (There were no records at EPA der onstrating that DCBA was ever a registered pesticide. I structure is somewhat similar to dicamba, and less simil to 2,4-D.)

TABLE 6
Soil-Core Analysis Results

Sample Description and Location	Organic Matter %	Technical Chlordane (ppb)			Heptachlor Epoxide (ppb)		
		Found	MDL	GC/MS	Found	MDL	GC/M
Eastward Ho! #6 Fairway:							
1'-1.5'	3.0	334	5	NR	7.7	0.6	NR
2'-3.5'	0.8	ND	5		ND	0.6	
4'-4.5'	0.3	ND	5		ND	0.6	
6'-7.5'	0.2	ND	5		ND	0.6	
Falmouth #17 Green:							
0'-1.5'	2.3	4310	5	NR	39	0.6	NR
8'-9.5'	0.3	85	5	C	0.86	0.6	C
15'-16.5'	0.07	29.5	5	NR	ND	0.6	
24'-25.5'	B	ND	5		ND	0.6	
Hyannisport #16 Tee:							
0'-1.5'	2.0	2190	5	NR	199	0.6	NR
2'-3.5'	0.4	509	5	C	8.08	0.6	C
3.5'-5'	0.2	4.75*	5	NR	0.73	0.6	NR
5.8'-7.3'	0.2	ND	5		ND	0.6	

Six other pesticides were analyzed for but never detected. Pesticides and MDLs (in ppb) were dacthal, 0.5-5; chlorothalonil, 0.3-5; isofenphos, 15-1 chlorpyrifos, 1-10; diazinon, 4; anilazine, 20. (The highest MDLs usually only arose in samples from the topsoil, which often contained many interference

MDL — method detection limit
NR — not run
ND — not detected
C — confirmed by GC MS (qualitative)
B — broken sample
* - Slightly below MDL but sample afforded reliable quantitation

TABLE 7
Ground Water Organic Analysis Results

Analyte	MDL	Bass River B	Bass River T	Bass River F	Bass River G	Eastward Ho! B	Eastward Ho! T	Eastward Ho! F	Eastward Ho! G	Falmouth B	Falmouth T	Falmouth F	Falmouth G	Hyannisport B	Hyannisport T	Hyannisport F
Technical Chlordane	0.125	ND	0.96 (0.49-1.17)	ND	0.11 (ND-0.34)	ND	ND	ND	ND	ND	0.12 (ND-0.23)	ND	0.10 (ND-0.21)	ND	0.32 (ND-0.96)	0.39 (ND-1.39)
Chlorothalonil	0.015	ND	ND	ND	0.08 (ND-0.38)	ND	ND	ND	ND	ND	0.05 (ND-0.22)	ND	ND	ND	ND	ND
Chlorpyrifos	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.04 (ND-0.1)	ND	ND	ND
2,4-D	0.05	ND	ND	ND	0.10 (ND-0.24)	ND	ND	ND	ND	ND	ND	—	ND	ND	ND	ND
Dacthal Diacid	0.20	ND	0.16 (ND-0.21)	ND	ND	ND	ND	ND	0.29 (ND-1.07)	ND	0.16 (ND-0.35)	—	ND	ND	ND	ND
Dicamba	0.05	ND	ND	ND	ND	ND	ND	0.03 (ND-0.06)	ND	ND	ND	—	ND	ND	ND	ND
2,4-Dichlorobenzoic Acid (DCBA)	0.20	0.24 (ND-0.42)	9.38 (ND-32)	0.05 (ND-0.08)	‡ (ND-298)	0.14 (ND-0.24)	5.82 (ND-8.94)	0.13 (ND-0.21)	0.89 (ND-3.26)	ND	ND	—	ND	ND	0.13 (ND-0.36)	ND
Heptachlor Epoxide	0.03	ND	0.04 (0.03-0.06)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.05 (ND-0.16)	0.04 (ND-0.08)
Isofenphos	0.75	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.57 (ND-1.17	ND	ND	ND
3,5,6-Trichloro-2-Pyridinol	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	—	ND	ND	0.24 (ND-0.76)	ND

* All results in µg/L. Average concentration provided (assuming ND = ½ MDL), followed by range in parentheses. Seven other analytes were never detected (see Table 3)
MDL = method detection limit. B = background well. T = tee well. F = fairway well. G = green well.
‡ Highest DCBA concentrations should be viewed qualitatively only since analytical difficulties were experienced in the initial sampling round. Subsequent concentration typically 2 to 10 ppb.

Three conclusions can be drawn from this assessment: (1) pesticides and related compounds were found in areas where pesticides are more intensively applied—the greens and tees—according to superintendents' records; (2) chemicals that may have leached to ground water under greens and tees do not appear to have migrated extensively to the other wells; and (3) the mystery compound—DCBA—was the only organic chemical ever detected in the background wells. This suggests the possibility of an off-site source. This point is discussed later.

Temporal Trends

This study was limited to four complete rounds of sampling over a one and a half year period. Therefore one would not expect many temporal trends to become apparent. Only one temporal trend was noted in organic analysis results. There were significant declines in pesticide concentrations between the first round of sampling and the second round, and between the second and third rounds. Between the first and second rounds of sampling, 14 detections of chemicals in wells declined and six increased. Between the second and third rounds, 10 detections of chemicals in wells declined and three increased. This trend is consistent with the possibility of cross contamination during well installation. Due to a scheduling mixup, the 16 drive-and-wash wells were installed without the presence of a practicing geologist. A 2 to 3 foot plug of bentonite was used to seal the borehole above the well screens, but native soil was used to backfill the annular space above the bentonite plug. Thus it might be possible for pesticides to desorb from contaminated surficial soil and leach to ground water, especially if the bentonite seal is not complete. (Note the high surficial chlordane concentrations in Table 6.) In addition, the wash-and-drive techniques itself may have introduced cross contamination. Water level records for the time period show a general, but small decline. However, this apparent

TABLE 8
Nitrate-N Ground Water Results*

Golf Course-Well	1986			1987-1988			Overall
	Average	Median	Range	Average	Median	Range	Average
Bass River							
B	8.36	8.00	5.60-12.0	6.78	7.00	5.60- 7.50	8.02
T	2.21	1.30	0.20- 7.00	0.52	0.50	0.10- 1.00	1.03
F	3.98	4.00	1.30- 6.50	6.16	6.00	4.40-10.00	4.16
G 3							
G-2	1.27	1.25	0.10- 3.21	4.65	4.80	0.10- 9.00	2.79
Eastward Ho!							
B	0.10	0.10	0.10- 0.10	0.10	0.10	ND-0.10	0.10
T	1.81	1.50	0.10- 5.00	0.40	0.40	ND-0.80	0.99
F	11.90	13.00	0.10-20.0	4.10	3.20	1.80-10.0	6.66
G	11.26	9.00	2.80-30.0	3.03	3.00	1.40-5.00	6.31
Falmouth							
B	0.10	0.10	0.10- 0.10	0.10	0.10	ND-0.10	0.10
T	0.74	0.70	0.40- 1.80	1.58	1.55	1.10-2.40	1.54
F		(not sampled)			(2 samples — 0.30 and 0.10)		
G	2.52	1.50	0.40- 6.50	1.40	0.65	0.50-6.00	2.44
Hyannisport							
B	0.11	0.10	0.10- 0.20	0.10	0.10	ND-0.10	0.10
T	2.25	2.20	0.80- 3.00	1.50	1.50	1.00-4.80	2.24
F	3.46	3.60	0.60- 6.00	2.60	2.60	1.40-6.50	3.24
G	7.62	7.50	4.00-10.20	4.36	4.20	1.40-6.50	5.82

* Results in mg/L. Detection limit = 0.10 mg/L.
ND — non-detect (0.1 values do reflect detections)
B — background well, T — tee well, G — green well, F = fairway well.

decrease in recharge may not be sufficient to explain the declines in pesticide concentration.

The last round of pesticide results would be the ones least likely to be influenced by well installation. Therefore, it is interesting to note that pesticides were detected in only five wells in the final round of sampling—at Bass River (green and tee), Hyannisport (green), and Eastward Ho! (green and fairway). Chlordane was only detected once, at Hyannisport. The other pesticides were DCBA, dacthal diacid, and dicamba.

Three hollow-stem auger wells were installed in 1987 (Table 1). Two of these wells were installed to try to resolve the question of cross contamination. Unfortunately, the results were equivocal. One well yielded no chlordane detections, for example, and the other one did (0.22 ppb). However, the second well was approximately 2 to 3 feet from an original drive-and-wash well that contained chlordane, leaving open the question of whether chlordane reached ground water through the nearby borehole or more regionally. The chlordane results are discussed further in following text.

Some of the explanation of the initially high concentrations of DCBA may be due to the fact that the laboratory had not set up to analyze for this unexpected inpurity, and encountered a high variability in their initial analyses. Therefore the first round DCBA results should be regarded as qualitative.

Toxicological Significance of the Results

The detected chemicals, their health guidance levels (HGLs)—calculated according to the procedure i "Chemical Selection" discussed previously—and the rati of the maximum concentrations to the HGLs can b listed as follows:

Chemical	HGL (ppb)	([C]max)/HG
chlordane	0.03	240
chlorothalonil	2	0.2
chlorpyrifos	5	0.02
2,4-D	70	0.003
dacthal (+ diacid)	500	0.002
dicamba	200	0.0003
2,4-DCBA	*	
heptachlor epoxide	0.004	40
isofenphos	35	0.06
3,5,6-trichloro-2-pyridinol	**	

* Unknown, but probably >50 ppb based on its structural class (chlorinate benzoic acid) and its similarity to dicamba.
** A chlorpyrifos metabolite that has lost the molecular fragment most responsible for chlorpyrifos' toxicity.

This indicates that only chlordane and its weathere impurity were present at concentrations producing lon term health concerns following long-term exposure. Th high ([C]max)/HGL ratio of chlordane and heptachlc epoxide was due more to the low HGLs for these com pounds rather than high concentrations.

Chlordane use on turf is no longer allowed. Therefor none of the 12 currently registered turf pesticides targete in this study were detected in concentrations greater tha one-fifth of the HGL.

Pesticide Mobility and Persistence

Guidance for making judgments about the relative mobility and persistence of pesticides has appeared elsewhere (Cohen et al. 1984, Gustafson 1989). Basically, pesticides that are very mobile and very persistent have a high probability of leaching to ground water in vulnerable environments.

Following is a subjective, simplistic assessment of the mobility and persistence of the pesticides targeted in this study. The rankings below are based on published literature, personal experience, and educated guesses. (The Gustafson (1989) and Cohen et al. (1984) references also cite other articles with good pesticide chemistry data.)

Mobility

High	Medium	Low
2,4-D	siduron	chlordane
2,4-DCBA	PCP	heptachlor epoxide
dicamba	iprodione	dacthal
dacthal diacid	trichloropyridinol	chlorothalonil
MCPP	diazinon	chlorpyrifos
	isofenphos	anilazine

Persistence

High	Medium	Low
chlordane	iprodione	2,4-D
siduron	dicamba	MCPP
PCP	isofenphos	dacthal
2,4-DCBA	dacthal diacid	
heptachlor epoxide	chlorothalonil	
	chlorpyrifos	
	trichloropyridinol	
	anilazine	
	diazinon	

By these subjective criteria, a moderately mobile chemical would have a Koc (soil organic carbon/water partition coefficient) roughly between 500 and 1200. A moderately persistent chemical would have soil metabolism and hydrolysis half lives of approximately two to eight weeks and one to six months, respectively.

Thus this study examined pesticides with a broad cross section of pesticide mobility and persistence.

Chlordane Results

Initially, the chlordane findings were especially puzzling. Chlordane is persistent and had a high label rate for turf, but it is immobile. However, a small study was done that demonstrated that chlordane in the ground water was removed when the water was passed through a 20 to 25μ filter. Thus it is reasonable to assume that chlordane migrated to ground water via facilitated transport, i.e., via macropore flow in the bound phase and/or via cross contamination during well installation (see the previous Temporal Trends discussion). The nature of dense, healthy turf, and the presence of poorly aggregated sands would tend to argue against macropore flow, but this point cannot be proven either way.

Comparison With Other Data

The Cape Cod study is the only one of its kind. Turf-plot lysimeter studies of 2,4-D and dicamba (Gold e al. 1988) and nitrate (Morton et al. 1988) have demon strated minimal losses of these solutes in root zon leachate. This may be due to the dense root and shoo system of turf, coupled with a surficial thatch layer.

The concentrations and frequencies of occurrence o these turf chemicals in ground water are generally les relative to typical findings of agricultural chemicals i row crop and field crop culture (Cohen et al. 1986, U.S EPA 1988(b)). U.S. EPA (1988(b)) and Cohen et al. (1986 summarized monitoring data frequently obtained fron vulnerable environments, analogous to Cape Cod. How ever, in one sense the comparison may not be vali because some of the more mobile and persistent pesticide used in agriculture are used minimally in turf management In particular, nematicides were not applied to these gol courses. Certain nematicides can be mobile and persisten and are often detected in ground water in agricultura areas. Nematicides are applied to turf in more southen areas.

Nitrates

Different nitrogen management practices tended t influence the extent to which nitrate-N leached to groun water. The Falmouth golf course seemed to use the highes proportion of slow-release nitrogen fertilizers, and it ha the lowest concentration of nitrate-N in ground water The Eastward Ho! golf course had the greatest nitrate-N ground water concentrations in 1986, and also tended t apply more water-soluble nitrogen. When nitroge application was significantly reduced in 1987, groun water concentrations of nitrate-N were also significantl reduced. These trends cannot be explained by the rainfal data summarized under the Regional Hydrogeolog section.

These encouraging results indicate that reasonabl changes in management practices can minimize nitrat contamination in the types of environments that wer studied.

Conclusions

Eight pesticides and pesticide metabolites and tw pesticide impurities were found in ground water at the study sites. Only chlordane/heptachlor, a banned pesticide formulation, was found in toxicologically significan concentrations. Therefore use of turf pesticides by four golf courses with vulnerable hydrogeology was found to have minimal impact on ground water quality; however, some of the contamination may also have been due to preferential flow through macropores.

This study was done with one set of pesticides in one hydrogeologic environment. It is recommended that additional studies of this type be done in different hydrogeologic settings and include some nematicides. Nematicides tend to be more mobile and persistent than other pesticide classes, with the possible exception of systemic herbicides, and they tend to be used more in southern climates. Additional hydrogeologic settings worth studying include areas with enhanced secondary permeability such as karst environments or areas of shallow fractured bedrock.

The study indicated that turf management practices are closely related to nitrate concentrations in ground water. Rate and frequency of fertilizer application as well as type of fertilizer used appear to be significant factors in ground water nitrate-nitrogen concentrations beneath managed areas. In at least one instance, reduced fertilizer application correlated with a decline in nitrate concentrations.

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Note

The views expressed here are those of the authors and do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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The Fate of Nitrogenous Fertilizers Applied to Turfgrass

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ABSTRACT

Maintaining high quality surface and groundwater supplies is a national concern. Nitrate is a widespread contaminant of groundwater. Nitrogenous fertilizer applied to turfgrass could pose a threat to groundwater quality. However, a review of the fate of N applied to turfgrass is lacking, but needed in developing management systems to minimize groundwater contamination. The discussion of the fate of N applied to turfgrass is developed around plant uptake, atmospheric loss, soil storage, leaching, and runoff. The proportion of the fertilizer N that is taken up by the turfgrass plant varied from 5 to 74% of applied N. Uptake was a function of N release rate, N rate and species of grass. Atmospheric loss, by either NH_3 volatilization or denitrification, varied from 0 to 93% of applied N. Volatilization was generally <36% of applied N and can be reduced substantially by irrigation after application. Denitrification was only found to be significant (93% of applied N) on fine-textured, saturated, warm soils. The amount of fertilizer N found in the soil plus thatch pool varied as a function of N source, release rate, age of site, and clipping management. With a soluble N source, fertilizer N found in the soil and thatch was 15 to 21% and 21 to 26% of applied N, respectively, with the higher values reflecting clippings being returned. Leaching losses for fertilizer N were highly influenced by fertilizer management practices (N rate, source, and timing), soil texture, and irrigation. Highest leaching losses were reported at 53% of applied N, but generally were far less than 10%. Runoff of N applied to turfgrass has been studied to a limited degree and has been found seldom to occur at concentrations above the federal drinking water standard for NO_3^-. Where turfgrass fertilization poses a threat to groundwater quality, management strategies can allow the turfgrass manager to minimize or eliminate NO_3^- leaching.

THE IMPORTANCE of maintaining high-quality surface and groundwater supplies cannot be overstated. Groundwater accounts for 86% of the total water resources in the contiguous USA and provides 24 to 95% of the drinking water supply for urban and rural areas, respectively (Scott, 1985). The dependence on groundwater supplies is increasing at a faster rate than for surface water (Solley et al., 1983). A wide range of contaminants are found in groundwater. Nitrate (NO_3) is considered one of the most widespread groundwater contaminants (Pye et al., 1983). Sources of NO_3^- contamination include effluent from cess pools and septic tanks, animal and human wastes, and fertilization of agricultural lands (Keeney, 1986). Nitrate leaching from fertilizers applied to turfgrass sites has been proposed as a major source of nitrate contamination of groundwaters in suburban areas where turfgrass is a major land use (Flipse et al., 1984).

To date, a comprehensive review of the effect of N applied to turfgrass on groundwater quality is lacking or has been ignored in another review (Keeney, 1986). The purpose of this paper is to provide a review and critical analysis of the current state of knowledge of the effect of nitrogenous fertilizers applied to turfgrass on groundwater quality. This review can be useful in providing information on the development of best management practices to minimize the impact of turfgrass fertilization on groundwater quality and to indicate gaps in the knowledge base, which can emphasize future research needs.

The discussion of the fate of N applied to turfgrass will cover the five major categories of the N cycle: plant uptake, atmospheric loss, soil storage, leaching, and runoff. As illustrated in Fig. 1, N can be found in both organic and inorganic forms in the turfgrass

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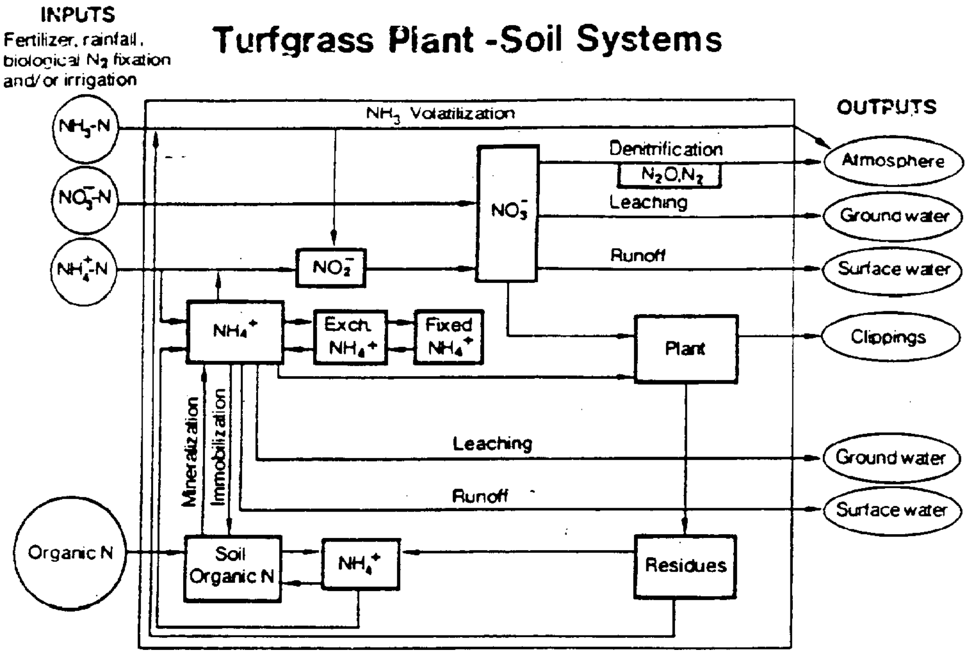

Fig. 1. The N cycle for the turfgrass ecosystem.

plant-soil system. Inputs of N into the system are primarily from fertilizers but to a lesser extent from rainfall, irrigation, and biological N_2 fixation. Once the N is in the turfgrass plant-soil system it may be found in one of the N pools of NO_3^-, NH_4^+, soil organic N or as part of the turfgrass plant. Nitrogen leaves the system via several routes: gaseous loss to the atmosphere (NH_3 volatilization and denitrification), leaching into groundwater, runoff into surface water, and removal in the clippings of the turfgrass plant.

Plant Uptake

The goal of an environmentally sensitive N management system is to optimize the amount of N uptake by the plant. However, the uptake of N is influenced by numerous factors including temperature and moisture that affect plant growth rate, available N pool, N source and rate, and the genetic potential differences between species and/or cultivars. With numerous factors influencing the amount of N taken up by a plant, direct comparisons of results of research from various experiments are somewhat difficult. However, this section summarizes and evaluates the results of numerous studies (Table 1) of the plant uptake of fertilizer N for grasses used for either turf and nonturf type situations.

Grass species and grass use patterns have a major impact on N recovered in clippings. Barraclough et al. (1985) observed that 99% of the fertilizer N, applied as ammonium nitrate (NH_4NO_3) at an N rate of 250 kg ha^{-1} yr^{-1} was recovered in the single harvest of the shoots of perennial ryegrass (*Lolium perenne* L.), whereas the N recovery in the clipping steadily declined with increased N rates to about 50% fertilizer N recovery at an N rate of 900 kg ha^{-1} yr^{-1}. In contrast, about 60% of the fertilizer N was recovered in the season long clippings yields of the 'Penncross' creeping bentgrass (*Agrostis palustris* Huds.) when fertilized at an N rate of 240 to 287 kg ha^{-1} yr^{-1} (Sheard et al., 1985). Cisar et al. (1985) found that 'Enmundi' Kentucky bluegrass (*Poa pratensis* L) had N uptake rates in the field of 4.6 g N m^{-2} d^{-1} compared with 3.1 g N m^{-2} d^{-1} for 'Yorktown II' perennial ryegrass.

Recovery of fertilizer N in the clippings of Kentucky bluegrass has been studied more thoroughly and found to be highly influenced by the rate at which N becomes available from various N sources during the growing season. Nitrogen recovery via clipping removal ranges from 25 to 60% from N sources from which most of the N is released during a single year. Over a 3-yr period, N recovery in the clippings averaged 46 to 59% of the 245 kg N ha^{-1} yr^{-1} supplied by sulfur-coated urea (SCU), isobutyldine diurea (IBDU), and NH_4NO_3 (Hummel and Waddington, 1981). Others have found similar (Hummel and Waddington, 1984) or slightly lower (Selleck et al., 1980; Starr and DeRoo, 1981) recovery with similar N sources and rates. However, with sources from which N is not entirely released in 1 yr, N recovery in the clippings is considerably less. Recovery of applied N in clippings was 22% from ureaformaldehyde, 29% from activated sewage sludge, 11% from ammeline, and 5% from melamine (Hummel and Waddington, 1981; Hummel and Waddington, 1984; Mosdell et al., 1987).

A comparison of two highly water-soluble N sources showed that 53% of the applied N from NH_4NO_3 was recovered in the clippings of an infrequently harvested perennial ryegrass compared with 31% recovery from urea (Watson, 1987). Although, little difference in turfgrass quality has been shown between turfgrasses treated with either urea or NH_4NO_3 (Rieke and Bay, 1978), one would expect a difference in quality due to a difference in uptake substantial as that reported by Watson (1987). The rate of N applied has a variable effect on N recovery in the clippings. At N rates less

Table 1. Uptake of fertilizer N by turfgrasses.

Grass	Use	Clipping Frequency	Clipping Placement	Nitrogen Source	Nitrogen Rate	Nitrogen Season	Soil texture¶	Plant uptake Clippings	Plant uptake Other†	Reference
		days			kg N ha⁻¹			% of applied		
Agrostis palustris Huds 'Penncross'	Putting green	4–13	removed	Urea	287	Year	Sand	60	–	Sheard et al. (1985)
Lolium perenne L. 'Melle'	Forage	5 yr⁻¹	removed	NH_4NO_3	250	Year	Sandy loam	99	–	Barraclough et al. (1985)
					500			76	–	
					900			50	–	
Lolium perenne L. 'Melle'	Forage	once, 7 wks		Urea	90		Sandy loam	31	16	Watson (1987)
				NH_4NO_3	90			53	25	
Poa pratensis L. 'Merion'	Lawn	7	removed	SCU-11‡	245	Fall	Hagerstown silt loam	32	1.9	Hummel and Waddington (1984)
					245	Spring		37	2.3	
					245	Spring/fall		33	2.1	
					147	Spring/fall		25	2.7	
				Ureaformaldehyde	245	Spring/fall		22	2.2	
				IBDU	245	Spring/fall		46	2.0	
				NH_4NO_3	245	Spring/fall		59	2.1	
					147	Spring/fall		53	3.1	
Poa pratensis L.	Lawn	7	removed	Not stated	100	Year	Haven-Riverhead sandy loam	36	39	Selleck et al. (1980)
					200			36	31	
					400			35	20	
Poa pratensis L. and *Festuca rubra* L.	Lawn	7	removed	$(NH_4)_2SO_4$	180	Spring/fall	Merrimac sandy loam	29	–	Starr and DeRoo (1981)
			returned					30	–	
Poa pratensis L. 'Baron'	Lawn	7	removed	IBDU-course	197	Spring/fall	Hagerstown silt loam	37	–	Hummel and Waddington (1981)
				IBDU-fine				47	–	
				Ureaformaldehyde				22	–	
				Activated sewage sludge				29	–	
				Methylene urea				42	–	
				$(NH_4)_2SO_4$				48	–	
Poa pratensis L. 'Wabash'	Lawn	12–15	removed	Melanie	98	Summer	Chalmers silt loam	5	–	Mosdell et al. (1987)
				Ammeline				11	–	

Table 1 (cont.)

than optimum for shoot growth, increasing the rate of N will result in an increase in the percentage N recovered in the clippings (Selleck et al., 1980; Wesely et al., 1988). When rates are near optimum for shoot growth, the recovery was not influenced by the increase in the rate of N applied (Hummel and Waddington, 1984; Selleck et al., 1980; Wesely et al., 1988). Furthermore, at higher than optimum rates, percentage of N recovered generally declined (Barraclough et al., 1985; Halevy, 1987; Selleck et al., 1980).

Limited information exists on the percentage of fertilizer N recovery in the clippings as influenced by soil type. In one study 9% more of the fertilizer N was found in the clippings from plants grown on a silt loam soil than a clay loam soil (Webster and Dowdell, 1986). The difference was found to relate to greater amounts of leaching, denitrification, and/or storage of N in the clay loam soil.

Season, temperature, and irrigation also have some effect on fertilizer N recovery in clippings. Spring-applied SCU was found to enhance total N recovery in the clippings over fall-applied material (Hummel and Waddington, 1984). In a growth chamber, Mosdell and Schmidt (1985) observed that at day/night temperatures of 16 °C/4 °C from 26 to 39% of fertilizer N was recovered in the clippings of Kentucky bluegrass. However, at temperatures of 30 °C/24 °C, N removal in the clipping was no greater in pots fertilized with either NH_4NO_3 or IBDU at a N rate of 74 kg ha⁻¹ than on the unfertilized pots.

Clipping management should be expected to influence fertilizer N recovery in the clippings (Rieke and Bay, 1976), but Starr and DeRoo (1981) found almost identical amounts of fertilizer N (29%) in the clippings on plots either having the clippings returned or removed.

The amount of fertilizer N found in other plant parts (roots, crowns, stems) has been studied to a lesser extent. Selleck et al. (1980) observed that the percentage of fertilizer N found in verdure, crowns, roots, and

Table 1. (Continued).

Grass	Use	Clipping		Nitrogen			Soil texture¶	Plant uptake		Reference
		Frequency	Placement	Source	Rate	Season		Clippings	Other†	
		days			kg N ha^{-1}			— % of applied —		
Poa pratensis L. 'Park'	Lawn	7	removed	Urea	9	Spring	Sharpsburg silty clay loam	49	–	Wesely et al. (1988)
					18			60	–	
					27			59	–	
					36			59	–	
Lolium perenne L. 'Engels'	Forage	21	removed	IBDU	1120	Glasshouse	Sand	71	–	Halevy (1987)
					2240			41	–	
					3360			22	–	
					4480			12	–	
				SCU	1120			64	–	
					2240			42	–	
					3360			25	–	
					4480			15	–	
				Urea	373			71	–	
					746			70	–	
					1307			64	–	
					2053			44	–	
Unspecified	Forage	7	removed	$Ca(NO_3)_2$	400	Year	Clay loam	52	–	Webster and Dowdell (1986)
					400		Silt loam	63	–	
Poa pratensis L. 'Adelphi'	Lawn	Once, 70	removed	NH_4NO_3	74		Lodi silt loam			Mosdell and Schmidt (1985)
						16 °C/4c L§		12	–	
						H		39	–	
						30 °C/24c L		0	–	
						H	0	–		
				IBDU		16 °C/4c L		26	–	
						H		43	–	
						30 °C/24c L		0	–	
						H		0	–	

† Other plant parts including roots, stems, and verdure.
‡ Sulfur-coated urea, 36% N with 11% 7-d dissolution rate.
§ Growth chamber study, day and night T; L and H refer to 2.5 and 5.0 cm of irrigation wk^{-1}, respectively.
¶ Hagerstown, fine, mixed, mesic Typic Hapludalfs; Haven-Riverhead, mixed, mesic Typic Dystrochrepts; Merrimac, sandy, mixed, mesic Typic Dystrochrepts; Chalmers, fine-silty, mixed, mesic Typic Haplaquolls; Sharpsburg, Typic Argiudolls; Lodi, clayey, kaolinitic, mesic Typic Hapludults.

debris (possibly thatch) was 39, 31, and 20% of applied N at N rates of 100, 200, and 400 kg N ha^{-1} yr^{-1}, respectively. Hummel and Waddington (1984) observed only 1.5 to 3% of the applied fertilizer N recovered in the unmowed portions of the plant (top, roots, and debris). The different results may be a function of the amount of thatch present as suggested by the results of Starr and DeRoo (1981). They found that 14 to 21% of the fertilizer N was found in the thatch layer. Neither Selleck et al. (1980) nor Hummel and Waddington (1984) provided thatch data; therefore, this explanation is only speculative.

Uptake of N from $(NH_4)_2SO_4$, as measured in the clippings of Kentucky bluegrass–red fescue (*Festuca rubra* L.) turf, occurred primarily within the first 3 wk after application (Starr and DeRoo, 1981). During the period from 3 to 9 wk after application, most of the N uptake was derived from the soil N pool and occurred at a rate (0.24 kg ha^{-1} d^{-1}) five times faster than that from fertilizer N. Clipping management during the 3 yr of this study had a major impact on total N uptake. About 9% of the total N found in the clippings was derived from the current year's returned clippings; whereas the N found in the clippings from the previous 2yr returned clippings accounted for 20% of the N in the clippings during the third year of the study.

ATMOSPHERIC LOSS OF FERTILIZER NITROGEN

Nitrogen applied as a fertilizer to turfgrass can be lost to the atmosphere as either ammonia (NH_3 volatilization) or as one of several nitrous oxide compounds (denitrification). Numerous factors influence the degree of NH_3 volatilization and denitrification as summarized in Table 2.

Ammonia volatilization can occur very rapidly following an application of N fertilizer such as urea. Factors that influence the amount of NH_3 volatilization include N source/form (liquid vs. dry) and rate, soil pH, amount of water (irrigation or precipitation) received after application and thatch. In addition, when urea was applied to bare soil and to turfgrass, the amount of NH_3 volatilization was higher in the turfgrass system than from bare soil (Volk, 1959). Thus, some other factor(s) related to the presence of turfgrass resulted in the acceleration of the NH_3 volatilization process.

Studies of NH_3 volatilization can be divided into field and nonfield studies. Results from the nonfield and/or closed system monitoring field studies are highly quantitative, and are useful for comparing treatment effects. Aerodynamic or other open system techniques can give results more typical of field conditions.

Table 2. Atmosphere loss of fertilizer nitrogen applied to turfgrass.

Grass	Location of study	Sampling period	Nitrogen Source	Nitrogen Single/total application rate	Soil moisture % saturation	Irrigation or rainfall	Temperature (relative humidity)	Soil texture§	NH_3 volatilization	Denitrification	Reference
				kg N ha⁻¹		cm	C (%)		% applied N	% applied N	
Poa pratensis L. 'Benson'	Field	3 d	Urea	58	–	0	27–39	Yolo loam	3–36	–	Bowman et al. (1987)
					–	0.5			2–21	–	
					–	1.0			1–8	–	
					–	2.0			1–5	–	
					–	4.0			0–3	–	
Poa pratensis L. 'Baron'	Growth chamber	10 d	KNO_3	52	75	–	22	Hadley silt	–	0.02	Mancino et al. (1988)
					75	–	>30		–	0.11	
					75	–	22	Hadley silt loam	–	0.4	
					75	–	>30		–	–	
					100	–	22	Hadley silt	–	5.4	
					100	–	>30		–	94	
					100	–	22	Hadley silt loan	–	2.2	
					100	–	>30		–	46	
Poa pratensis L.	Growth chamber	8 d	Urea	253	–	2.27 d⁻¹		Flanagan silt loam	5	–	Nelson et al. (1980)
								Thatch	39	–	
			IBDU		–			Flanagan silt loam	2	–	
								Thatch	4	–	
Poa pratensis L. and *Festuca rubra* L.	Field	8 d (July)	Urea	100	–	0			15.1	–	Sheard and Beauchamp (1985)
		5 d (August)			–	0.19			6.7	–	
Poa pratensis L. and *Festuca rubra* L.	Field	Growing season	$(^{15}NH_4)_2SO_4$	90/180	–	–		Merrimac sandy loam		24 / 36‡	Starr and DeRoo (1981)
Poa pratensis L. 'Merion'	Growth chamber	84 h	Urea (granular)	73	–	–	10	Crosby silt loam	18	–	Titko et al. (1987)
						–	22		43	–	
						–	32		61	–	
						–	(31)		39	–	
						–	(68)		61	–	
						0	–		51	–	
						2.5	–		2	–	
			Urea (dissolved)	73		–	10		3	–	
						–	22		17	–	
						–	32		12	–	
						–	(31)		2	–	
						–	(68)		12	–	
						0	–		16	–	
						2.5			5		
Poa pratensis L.	Growth chamber	21 d	Urea	293	–	–	24	Flanagan silt loam	10	–	Torello et al. (1983
			SCU						2		
		10 d	Urea (granular)	49	–	–	24		2		
			Urea (dissolved)						5		
		4 d	Ureaformaldehyde	49	–	–	24		3		
			Methyol urea						5		

† Values are a combination of NH_3 volatilization and denitrification for plots where clippings were returned.
‡ Values are a combination of NH_3 volatilization and denitrification for plots where clippings were removed.
§ Yolo, Typic Xeororthents; Hadley, coarse-silty, mixed, nonacid, mesic Typic Udifluvents; Flanagan, Aquic Argiudolls; Merrimac, fine, mixed, mesic Aeric Ochraqualfs.

Examining the results of studies from nonfield or closed systems field experiments, several important concepts can be put forth. An aspect of the turfgrass ecosystem that has a dramatic impact on NH_3 volatilization is the absence or presence of thatch. Nelson et al. (1980) observed that within 8 d after application of urea, 39% of the applied N volatilized as NH_3 from cores of Kentucky Bluegrass containing ≈5 cm of thatch but only 5% volatilized from cores having 5 cm of soil and no thatch below the sod. It should be noted that urea was applied at an extremely high N rate in this study (253 kg ha⁻¹). Substantial urease activity has been noted in the thatch layer, which is needed to convert urea to NH_3, and this activity serves to explain the role thatch plays in NH_3 volatilization (Bowman et al., 1987).

The source, rate, and form of N influences the pool of NH_3 available for volatilization. Torello et al. (1983) noted that 10% of the applied urea volatilized as NH_3 within 21 d after a single N application of 293 kg ha^{-1}, whereas only 1 to 2% of SCU N was volatilized as NH_3. At a lower rate of urea (49 kg ha^{-1}) only about 2% was volatilized. In general, Titko et al. (1987) observed more NH_3 volatilization with granular than dissolved urea. However, Torello et al. (1983) noted the opposite.

An estimate of NH_3 volatilization under field condition was observed by Sheard and Beauchamp (1985). Using an aerodynamic procedure they found that 15% of urea was lost by NH_3 volatilization from a bluegrass–red fescue sod fertilized at 100 kg N ha^{-1}.

Ammonia volatilization is influenced by the position of the N in the turfgrass system after application. The position is highly influenced by rainfall or irrigation. Bowman et al. (1987) studied the influence of irrigation on NH_3 volatilization after an application of liquid urea (49 kg N ha^{-1}). They observed a maximum of 36% NH_3 volatilization when no irrigation was supplied, whereas applying 1 and 4 cm of water within 5 min after application reduced NH_3 volatilization to 8 and 1%, respectively. Titko et al. (1987) also noted a significant reduction in NH_3 volatilization from either dry or dissolved urea applied to turfgrass that received 2.5 cm of irrigation. Irrigation after application dramatically affects the position of the urea. Without irrigation 68% of the urea was located in the shoots and thatch (Bowman et al., 1987). Irrigation at 0.5 and 1.0 cm reduced the percentage of urea found in the shoot and thatch to 31 and 26%, respectively. Urease activity was highly confined to the shoot and thatch region (97% on a dry wt. bases.). Sheard and Beauchamp (1985) also noted that NH_3 volatilization was reduced from 15 to 7% when a 1.2-cm rainfall occurred within 72 h after the urea application.

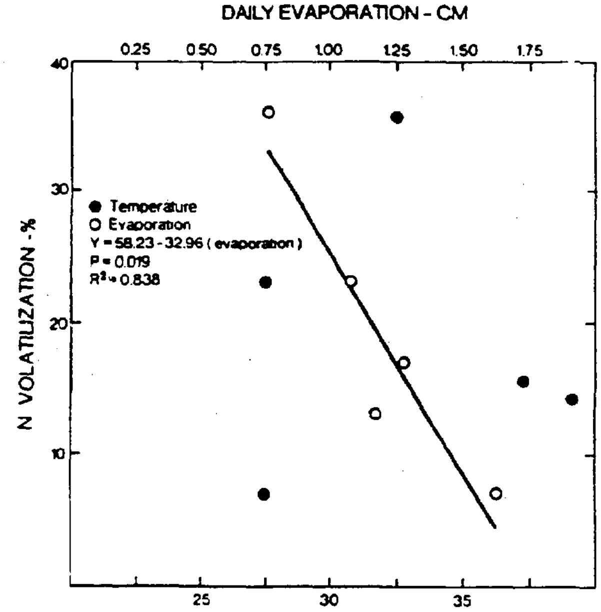

Fig. 2. Ammonia volatilization as influenced by maximum air temperature (●) and evaporation (O) the first 24 h after a liquid urea application (data from Bowman et al., 1987).

The rate at which liquid urea dries influences NH_3 volatilization. Ammonia volatilization from urea on nonirrigated sites is shown in Fig. 2. Ammonia volatilization appears independent of the maximum temperature recorded in the first 24 h after application. However, NH_3 volatilization was inversely related to the daily open pan evaporation rate. Furthermore, Titko et al. (1987) noted more NH_3 volatilization at 68% relative humidity than at 31% with either granular or dissolved urea.

Information regarding direct measurements of the magnitude of denitrification under turfgrass conditions is limited. Mancino et al. (1988) used the acetylene inhibition technique under laboratory conditions to measure the denitrification rate of KNO_3 applied to Kentucky bluegrass. They observed that when the soil was at a moisture content 75% of saturation, less than 1% of the N from KNO_3 was denitrified. Soil type and temperature had no effect on denitrification. However, when the soil was saturated, denitrification became significant. When temperatures were 22 °C or less, 2 and 5% of the N from KNO_3 was denitrified on a silt loam and silt soil, respectively. When temperatures were 30 °C or above, denitrification was substantial: 45 to 93% of applied N for the silt loam and silt soil, respectively. Thus, during periods of high temperatures, substantial losses of N by denitrification could occur in wet soils.

Starr and DeRoo (1981) studied the fate of N in turfgrass. Using a ^{15}N-labeled $(NH_4)_2SO_4$ to calculate a mass balance, they concluded that between 24 and 36% of the fertilizer N applied to Kentucky bluegrass–red fescue turf site was lost to the atmosphere by NH_3 volatilization and/or denitrification. The higher amount reflects clipping removal. When clippings were removed, less fertilizer N was found in the soil and thatch; thus, reducing the total amount of N accounted for and a higher calculated value of gaseous loss.

FERTILIZER NITROGEN STORED IN THE SOIL

When N in fertilizers, rainfall, or irrigation reaches the turfgrass-soil system, it may enter the inorganic pool (NH_4^+, NO_3^-), the organic pool, or be taken up by the plant.

Organic N must be converted through microbial activity to an inorganic form before it can be taken up

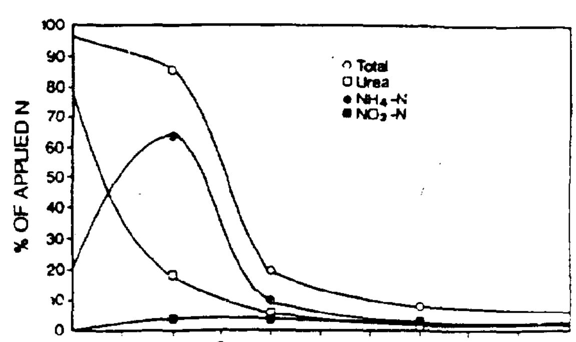

Fig. 3. Percentage of urea applied N recovered as urea, NH_4^+-N, and NO_3^--N as a function of time (data from Mosdell et al., 1987).

by the turfgrass plant. The rate of conversion is highly influenced by the form of the N, temperature, and moisture. At low temperatures or when soils are very dry, urea will not be converted to an inorganic form. However, in warm, moist soils, urea conversion is very rapid. Mosdell et al. (1987) followed the transformation process for urea (98 kg N ha^{-1}) applied to Kentucky bluegrass (Fig. 3). They observed that 76% of free urea was still present the day of treatment but little urea was found 4 d after treatment (DAT). Ammonium accumulation peaked at 2 DAT. The amount of NO_3-N never exceeded 4% of the applied N.

The conversion of other N sources often takes a slightly different pathway than that for urea. Urea in SCU must escape the S coating before conversion. Urea is liberated by hydrolysis from IBDU. Organic N forms (e.g., activated sewage sludge), like any other component of the soil organic matter pool, must be mineralized to NH_4^+ then can be nitrified to NO_3^-.

The amount of fertilizer N stored in the soil is influenced by the release rate of different N source, clippings management and organic matter content as reflected in the age of the turfgrass site (Table 3). The source of N is important when considering sources that have delayed N release. Waddington and Turner (1980) determined the amount of undissolved SCU pellets at selected time intervals after the application (Table 4). They noted that SCUs with lower dissolution rates (% N dissolved after 7 d) and more S coating had a larger amount of residual SCU pellets recovered. In a short-term control environmental chamber study using Kentucky bluegrass, Nelson et al. (1980) determined the percent of residual fertilizer N in a 5.3-cm deep core, containing either soil or thatch, treated at an extremely high single N application rate of 253 kg ha^{-1}. Fifteen days after treatment, only 2% of the urea-N was left in cores with thatch compared with 58% without thatch. For IBDU, the amounts recovery of IBDU-N was 96% from cores with thatch and 67% from cores without thatch.

Determining the amount of fertilizer N that is eventually incorporated into soil organic matter is difficult, thus only a few studies have been done. Nitrogen stored in the soil is not all from fertilizer N; therefore, a tracer for the N in the fertilizer is necessary. Commonly, a ^{15}N source is used for this purpose. Starr and DeRoo (1981) fertilized a Kentucky bluegrass–red fescue turf with $(NH_4)_2SO_4$ containing ^{15}N. They found at the end of the year (4 months after last application) that 15 to 21% of the fertilizer N was stored in the soil. The lower value was from treatments from which clippings were removed. Also, they noted that 21 to 26% of the fertilizer N was found immobilized in the thatch layer, again the lower number is from treatment with clippings removed. Other studies using ^{15}N applied to perennial ryegrass have shown similar results. Watson (1987) noted that 13 and 17% of the applied N was found in the soil organic N pool 7 wk following an application with urea and NH_4NO_3, respectively. Webster and Dowdell (1986) found between 20 and 24% of the fertilizer N remained in the organic N pool soil 4 yr after the final appliction.

The results of the research cited above indicate that 15 to 26% of the N applied by urea, NH_4NO_3, and $(NH_4)_2SO_4$ is present as organic soil N within 4 months to 4 yr after application. If N in thatch (Starr and

Table 3. Soil storage of fertilizer N applied to turfgrass.

Grass	Soil texture	Nitrogen Source	Nitrogen Rate	Days from last treatment	Clipping management	Thatch N	Soil N	References
			kg N ha^{-1}			% of applied N		
Poa pratensis L.	Flanagan silt loam	Urea	253	15	Removed	–	58	Nelson et al. (1980)
		IBDU				–	67	
	Thatch	Urea				–	2	
		IBDU				–	96	
Poa pratensis L. and *Festuca rubra* L.	Merrimac sandy loam	$(NH_4)_2SO_4$	195	120	Returned	26	21	Starr and DeRoo (1981)
					Removed	21	15	
Lolium perenne	Sandy loam	Urea	90	49	Removed (once)	–	13	Watson (1987)
		$(NH_4)_2NO_3$				–	17	
Perennial grasses	Clay loam	$Ca(NO_3)_2$	400	1460	Removed	–	24	Webster and Dowdell (1986)
	Silt loam					–	20	

Table 4. Residual undissolved pellets on turfgrass fertilized with S-coated urea.

Source	Fertilizer characteristic† N	Sulfur coating	7-day dissolution rate	Months after last application 0	6	13	23	30
	%			% of applied N				
SCU-16w‡	37	21	15	15c*	17bc	6cd	3d	0d
SCU-17	34	27	17	37a	37a	21a	26a	13a
SCU-26w	37	19	27	3c	3c	1d	1d	0d
SCU-26	35	24	27	26b	23b	15b	17b	9b
SCU-35	36	22	35	14c	14cd	8c	8c	4c
Gold-N	30	34	37	3d	10de	3cd	4cd	1cd

* Values within columns followed by the same letter are not significantly different. (LSD Walker-Duncan, $k = 100$).
† Each material was applied on 16 May 1974, 20 May 1975, and May 1976 at a rate of 195 kg N ha^{-1} (from Waddington and Turner, 1980).
‡ SCU sources with a w have a 2% sealant; all other sources have a S coating only.

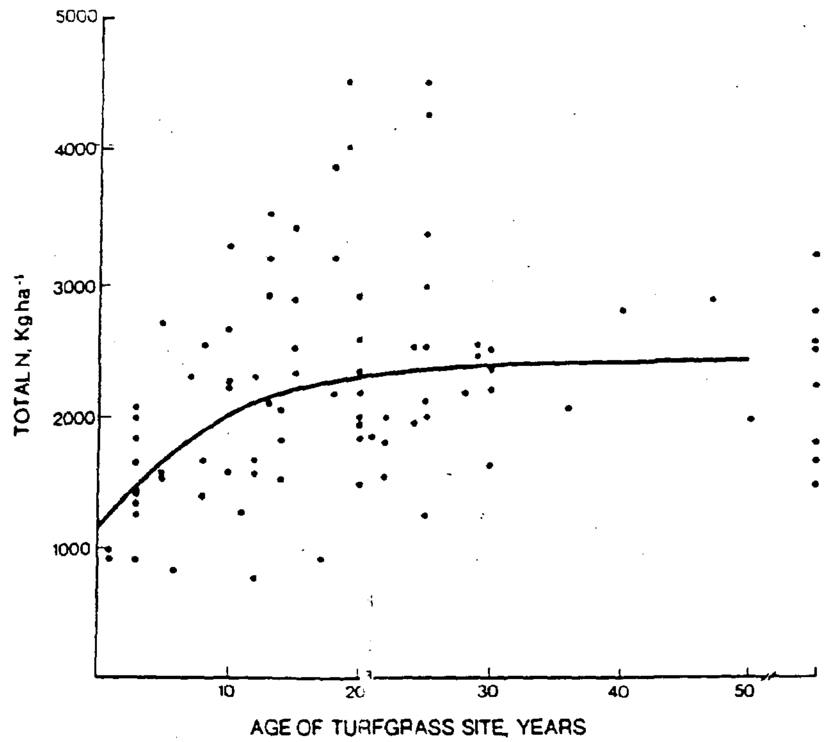

Fig. 4. Total N in surface layer of soil (0–10 cm) as a function of the age of the turfgrass site. Bulk density, 1.4 Mg m^{-3} (with permission from Porter et al., 1980).

DeRoo, 1981) is added to that in soil, then 36 to 47% of the fertilizer N becomes part of the organic N in the soil-thatch system.

Generally, when turfgrass is established on an area, the soil organic matter will increase for several years because of the increased input of organic matter to the soil (thatch, roots) and the lack of soil disturbance. During this period of increasing soil organic matter, some of the fertilizer N applied to the turf will be stored in the organic matter. Eventually, a new equilibrium will be established, and soil organic matter content will remain relatively constant. Therefore, the capacity of a turfgrass to store fertilizer N in the soil is a function of the age of the turfgrass. However, an exception would be when turfgrass is established on a soil that already has a relatively high organic matter content. Turfgrass would not increase organic matter, and consequently, little of the applied fertilizer N would be stored in the soil organic matter.

Only one attempt has been made to study soil N accumulation as a function of age of turfgrass sites. Porter et al. (1980) sampled 100 turfgrass sites ranging in age from 1 to 125 yr on Long Island, NY. Sites were chosen that had received somewhat uniform maintenance over a long period of time and from an array of turfgrass sites including residential lawns, golf course, church yards, and cemeteries. The level of maintenance was recorded and soil samples to a depth of 40 cm were collected and analyzed for total N. Figure 4 graphically depicts their results. Total N accumulation is very rapid in the first 10 yr and changes little after 25 yr. Thus, on younger sites (<10 yr in this example) the rate of N applied should match the rate at which N is stored in the soil, used by the plant and lost to the atmosphere. Older turf sites (>25 yr in this example) should be fertilized at a rate equal to the rate of removal by the plant and by loss to the atmosphere. Thus, old turf sites should be fertilized less to reduce the potential for NO_3^- leaching. Even though other cultural information was obtained in this survey (i.e., grass type, N rate, irrigation practices), only age influenced the storage of N in the soil. These factors could be important but due to the relative small sample population (100) the influence of these factors could not be determined.

LEACHING OF FERTILIZER NITROGEN APPLIED TO TURFGRASS

Several methods have been utilized in studying the leaching of fertilizer N. These include collection of drainage water, soil sampling, sampling of soil water above the saturated zone, trapping NO_3^- on ion exchange resins and sampling shallow groundwater. In most of these studies the assumption made was that once NO_3^- leaches past the root zone, it will eventually move into groundwater. This is true assuming little upward movement of water from below the root zone. A majority of the studies determined the degree of fertilizer N leaching by adjusting the values for background leaching from unfertilized plots. Starr and DeRoo (1981) used ^{15}N to more closely determine the fate of applied N.

The degree of NO_3^- leaching from a N fertilization of a turfgrass site is highly variable (Table 5). Some researchers reported little or no leaching, whereas others suggest that as high as 80% of the fertilizer N was leached as NO_3^-. Factors that influence the degree

Table 5. Summary of nitrate leaching from fertilizers applied to turfgrass.

Grass	Source	Nitrogen: Single N application rate	Nitrogen: Total yearly N rate	Season applied	Soil texture‡	Irrigation	% of Applied N leached	Concentrate of NO_3–N in water	References
		kg ha^{-1}	kg ha^{-1}			mm d^{-1}		mg L^{-1}	
Cynodon dactylon L.	Ureaformaldehyde	224	224	June	Sand/peat	6–8	–	0	Brown et al. (1977)
						8–10	–	<1	
						10–12	–	<1	
	NH_4NO_3	163	163	Feb.		6–8†	–	<1	
						8–10†	–	>10 for 20 d	
						10–12	–	>10 for 28 d	
	Milorganite	146	146	Oct.		6–8	–	<3	
						8–10	–	<6	
						10–12	–	<5	
	$(NH_4)SO_4$	24	24	Summer		12	37	<10	
		49	49			12	25	<10	
		73	73			12	22	>10 on 3 d	
		98	98			12	16	>10 on 3 d	
Cynodon dactylon L.	IBDU	146	146	June	Sand/peat	12	0.9	0	Brown et al. (1982)
					Sand/soil/peat	12	0.7	<2	
					Sandy loam soil	12	0.1	<1	
	Milorganite	146	146	Oct.	Sand/peat	12	7.7	0	
					Sand/soil/peat	12	2.4	<2.2	
					Sandy loam soil	12	0.5	0	
	Ureaformaldehyde	224	224	June	Sand/peat	12	0.2	0	
					Sand/soil/peat	12	0.3	0	
					Sandy loam soil	12	0.1	0	
	NH_4NO_3	163	163	Feb.	Sand/peat	12†	22	>10 for 25 d	
					Sand/soil/peat	12†	22	>10 for 25 d	
					Sandy loam soil	12†	8.6	>10 for 25 d	
Poa pratensis L. and *Festuca rubra*	Urea + fluf	49	98	June, Nov.	Merrimac sandy loam	1.8	–	0.87	Morton et al. (1988)
		49	98	June, Nov.		5.4	–	1.77*	
		49	245	June, July, Aug., Nov.		1.8	–	1.24	
		49	245	June, July, Aug., Nov.		5.4	–	4.02*	
		0	0			1.8	–	0.51	
		0	0			5.4	–	0.36	
Poa pratensis L. 'Adelphi'	NH_4NO_3	74	74	Cool	Lodi silt loam	3.6	0	–	Mosdell and Schmidt (1985)
				Cool		7.2	0	–	
				Warm		3.6	1.2	–	
				Warm		7.2	2.6	–	
	IBDU	74	74	Cool		3.6	2.7	–	
				Cool		7.2	0	–	
				Warm		3.6	0	–	
				Warm		7.0	0		
Poa pratensis L.	IBDU	245	245		Flanagan silt loam	2.3	26	–	Nelson et al. (1980)
					thatch	–	7	–	
	Urea			Warm	Flanagan silt loam	–	32	–	
					thatch	–	84	–	
Poa pratensis L.	Ureaformaldehyde	98	98	Nov.	Riverhead sandy loam	None	0–4	–	Petrovic et al. (1986)
	PCU (150D)						0–0	–	
	Milorganite						0–3	–	
	Urea						29–47	–	
	SCU						11–12	–	
Agrostis palustris Huds.	Urea	24	294	Whole year	Sand	Not given	2.0	<1.3	Sheard et al. (1985)
	SCU						1.2	<1.3	
Poa pratensis L. and *Festuca rubra*	Ammonium sulfate	88	176	May/Sept.	Merrimac sandy loam	None	0	0	Starr and DeRoo (1981)
Cynodon × *magenissii* H.	Check	0	0	Year	Pompano sand	As needed	0	–	Synder et al. (1981)

Table 5 (cont.)

Table 5. (Continued).

Grass	Source	Nitrogen: Single N application rate	Nitrogen: Total yearly N rate	Season applied	Soil texture‡	Irrigation	% of Applied N leached	Concentrate of NO_3-N in water	References
		—— kg ha^{-1} ——				mm d^{-1}		mg L^{-1}	
	Methylene Urea	39	245				<1	<1	
	Ureaformaldehyde						<1	<1	
	SCU						0	<1	
	IBDU						0.5	<1	
	Urea						0	<1	
	$Ca(NO_3)_2$						4.7	<1	
	Methylene Urea	78	490				2.0	<1	
	Ureaformaldehyde						0.1	1	
	SCU						0.8	<1	
	IBDU						5.5	1.4	
Cynodon × *magenissii* H.	Urea				Pompano sand		0.9	<1	Synder et al. (1981)
	$Ca(NO_3)_2$						9.3	2.4	
Cynodon × *magenissii* H.	NH_4NO_3	49	98	Feb.–Mar.	Pompano sand	6 (daily)	54.6	9.4	Synder et al. (1984)
	SCU						33.1	6.5	
	Fertigation						7.0	1.2	
	NH_4NO_3					1.5 (sensor)	40.5	14.4	
	SCU						11.2	4.0	
Fertigation							6.3	2.2	
	NH_4NO_3			June–July		3 (sensor)	8.3	3.2	
	SCU						1.6	0.8	
	Fertigation						0.8	0.1	
	NH_4NO_3					12 (daily)	22.2	3.2	
	SCU						10.1	1.4	
	Fertigation						15.3	2.1	
	NH_4NO_3			Apr.–May		3 (sensor)	1.9	6.2	
	SCU						0.3	1.0	
	Fertigation						0.3	1.0	
	NH_4NO_3					8 (daily)	56.1	18.9	
	SCU						14.4	4.8	
	Fertigation						3.5	1.2	

* Values significantly higher than unfertilized control plots ($P = 0.05$).
† Irrigation applied every other day.
‡ Riverhead, mixed, mesic Typic Dystrochrepts; Pompano, Typic Psammaquents.

of leaching were found to be soil type, irrigation, N source, N rates, and season of application.

Soil texture can have a dramatic effect on the leachability of N from turfgrass sites, because of its influence on the rate and total amount of percolating water, extent of denitrification, and to some degree ability of soil to retain NH_4^+. On an irrigated site in upper Michigan, Rieke and Ellis (1974) followed the movement of NO_3^- in a sandy soil (91% sand) to a depth of 60 cm by periodic soil sampling. Applying 290 kg N ha^{-1} as NH_4NO_3 each spring (six times the normal N single application rate), significantly elevated the NO_3^- concentration over that in the unfertilized plots in the 45- to 60-cm soil depth on only two of the 20 sampling during the 2 yr of the study. The results suggest only limited potential for NO_3^-. As expected, soil NO_3^- concentrations were highly elevated most of the 2 yr of the study in the surface 30 cm of the soil. Applying the same total amount of N in three applications revealed a similar trend. Sheard et al. (1985) observed that creeping bentgrass sand greens lost only 1.2 to 2.0% of applied N in the drainage water (N rate of 242–390 kg ha^{-1} yr^{-1}). The results on NO_3^- leaching from a U.S. Golf Association specification putting green were somewhat higher. The U.S. Golf Association specification putting greens have a minimum of 93% sand, a maximum of 3% silt and 5% clay, and an infiltration rate of at least 5 cm hr^{-1}. Brown et al. (1982) noted that 22% of NH_4NO_3-N leached as NO_3-N in the drainage water when N was applied in February at 163 kg ha^{-1} (three times the normal rate from bermudagrass (*Cynodon dactylon* L.) greens in Texas). However, the results from a Florida study (Synder et al., 1981) with bermudagrass sand greens revealed that average NO_3 leaching loss from urea over a 2-yr period was only 1% of applied N (78 kg ha^{-1} bimonthly). The mean NO_3-N concentration in the drainage water from this treatment was about 0.2 mg L^{-1}, well below the drinking water standard of 10 mg L^{-1}.

The information on NO_3 leaching from cool and warm season grasses grown on sandy loam soils is much more extensive. Brown et al. (1982), studying NO_3 leaching in bermudagrass greens built with a sandy loam soil, found that 9% of NH_4NO_3-N leached as NO_3 from a single application of NH_4NO_3 at 163 kg N ha^{-1} (three times the normal N application rate). Significant NO_3 leaching occurred from 10 to 40 DAT. Rieke and Ellis (1974) conducted a study in lower Michigan on a sandy loam soil identical to the one they conducted in upper Michigan on sand. Even though N was applied at six times the normal single N application rate (290 kg ha^{-1}), none of the treatments increased soil NO_3-N concentrations in the 45- to 60-cm soil depth over concentrations measured in the unfertilized Kentucky bluegrass plots. As before, soil NO_3-N concentrations in the surface soils were elevated but deeper movement of NO_3 appeared not to occur. Several others also have observed limited NO_3 leaching and on sandy loam soils, especially at normal N fertilization rates. Starr and DeRoo (1981) studied the fate of ^{15}N-$(NH_4)_2SO_4$ applied to Kentucky bluegrass–red fescue turf. They observed NO_3^--N concentration in the saturated soil zone (1.8–2.4 m deep) to range from 0.3 to 10 mg L^{-1} over the 3 yr of this field study. In only one sample did they find any ^{15}N and concluded that $(NH_4)_2SO_4$ applied at a yearly N rate of 180 kg ha^{-1} to a sandy loam soil in Connecticut did not result in NO_3^- contamination of groundwater.

Information on NO_3^- leaching from fertilizer N applied to turfgrasses grown on finer-textured soil is limited. Furthermore, the studies were conducted as short-term growth chamber experiments; thus, long-term field data are lacking. Nelson et al. (1980) studied the leaching potential of urea and IBDU applied to Kentucky bluegrass underlaid with either 5 cm of a silt loam soil or thatch. Applying 253 kg ha^{-1} (five times the normal rate) and collecting leachate for 15 DAT, they found that 32 and 81% of the applied urea leached as NO_3^- from the silt loam soil and thatch, respectively. Only 5 to 23% of the applied IBDU-N was leached from the thatch and silt loam soil cores, respectively. Nitrogen leaching losses with IBDU from the thatch were lower than from soil. Thatch has been shown to have a lower moisture retention capacity than soil (Hurto et al., 1980); thus, thatch could have dried between waterings and may not have been as favorable an environment for IBDU hydrolysis as soil. A conclusion one can draw from this work is that if NO_3^- is present in a soluble form above a concentration that can be used by the plant and if water moves through thatch or a silt loam soil (or any soil), then NO_3^- leaching can occur. If the N is not readily available, as in the case for IBDU, NO_3^- leaching losses were significantly less.

The impact of the source and rate of N on the leachability of N has received considerable attention. Most of the studies were conducted under the "worst case scenario," namely, sandy soils that were heavily irrigated and fertilized at several times the normal use rate. Others studies were conducted under less extreme conditions.

Generally, worst case scenario studies have shown that as the rate of N increased, the percent of the fertilizer N that leaches decreases; however, the amount of NO_3 leaching on an area basis was found to increase with increasing rates. Brown et al. (1977) observed that on putting greens containing root zone mixes of 80 to 85% sand, 5 to 10% clay, and up to 10% peat, the percent of N from $(NH_4)_2SO_4$ that leached as NO_3 in the drainage water decreased from 38 to 16% as the rate of N increased from 24 to 98 kg ha^{-1}. However, the amount of NO_3 leached increased from 9 to 15 kg ha^{-1}, which is important in terms of the concentration of NO_3-N in the drainage water. They noted, however, that when a fine sandy loam soil was used as the rooting zone media, the percent of fertilizer N that leached as NO_3 was reduced from 15 to 5% as the N rate increased. More importantly, the amount of NO_3-N that leached (4 to 5 kg ha^{-}) on an area basis was essentially unchanged as the N rate increased. Thus, increasing the rate of N applied to highly sandy greens would lead to a deterioration in the drainage water quality; whereas, on sandy loam greens, increased N fertilization would not further reduce the drainage water quality. Even at the high N rate of 98 kg ha^{-1} the drainage water exceeded drinking water standards for NO_3-N only 4 d. Furthermore, they observed considerably less NO_3 leaching from activated sewage sludge (Milorganite) or ureaformaldehyde, even when these materials were applied at very high single N application rates of 146 to 244 kg ha^{-1}.

Synder et al. (1981) also studied the N-leaching potential from sand as influenced by the source and rate of N. At a low rate of 39 kg N ha^{-1} applied bimonthly, they noted very little leaching with any N source. The highest leaching of inorganic N ($NO_3^- + NH_4^+$) was for $CaNO_3$, where 2.9% of applied N leached over 2 yr of the study. However, at a higher N rate of 78 kg ha^{-1} applied bimonthly, leaching occurred, in the order of 9.3 and 5% of applied N was leached from for $CaNO_3$ and IBDU, respectively. At the higher N rate, it appears that the amount of N for these two sources was applied in excess of that used by the plant, stored in soil, or lost to the atmosphere; thus, more leaching occurred. Less than 1% of the applied N was leached from ureaformaldehyde, SCU, and urea. The mean concentration of N in the leachate for $CaNO_3$ and IBDU-treated areas was 2.4 and 1.4 mg N L^{-1}, respectively, far below the safe drinking water standard of 10 mg L^{-1}.

Sheard et al. (1985) monitored N in the drainage water from creeping bentgrass sand greens. They observed that only 1.2 and 2.0% of the applied N (293 kg N ha^{-1} yr^{-1}) was collected as NO_3^- in the drainage water for an entire year on greens fertilized with either SCU or urea, respectively. They also noted very little difference between N leaching on acid (1.8%) on alkaline (1.4%) greens, from urea. Synder et al. (1981) found a big difference in N leaching between the soluble nitrate source ($CaNO_3$) and urea. They attributed the lower leaching from urea to greater NH_3 volatilization on the slightly alkaline sands. However, neither reported their post-irrigation irrigation practice, which has a major impact on the degree of NH_3 volatilization (Bowman et al., 1987).

The last example of studies on sandy soils with high N rates was from Rieke and Ellis (1974). In the upper Michigan site, a sandy soil (91% sand) received 122 cm of rainfall plus irrigation the first year and 83 cm the second, four N sources were applied in the spring at 378 kg ha^{-1}, a rate of eight times the normal single N application rate. As one would expect, NO_3^--N concentrations were significantly higher in the surface 30 cm of the soil most of the growing season. From their deepest sample (45 to 60 cm), NO_3^--N concentrations were significantly higher than those in the unfertilized plots one sampling date only. In this case more NO_3^- leaching was noted from NH_4NO_3, ureaformaldehyde, and IBDU than from activated sewage sludge.

Brown et al. (1982) studied the interaction of N source and soil texture on NO_3^- leaching from U.S. Golf Association specification greens of bermudagrass. Irrigation was provided to encourage some leaching into the drainage water. With root zone mixtures containing greater than 80% sand, leaching losses were 22% from NH_4NO_3, 9% from activated sewage sludge, and <2% from either ureaformaldehyde or IBDU. On greens constructed with a sandy loam soil, the losses were 9% from NH_4NO_3, 1.7% from activated sewage sludge, and <1% from either ureaformaldehyde or IBDU.

There are several reports on the effect irrigation has on the leaching potential of fertilizer applied to turfgrass. Morton et al. (1988) studied the effect of two N rates and two irrigation regimes on the leaching of N from a Kentucky bluegrass–red fescue lawn. The N rate was typical of a moderate to high lawn fertility program, of 50 urea and 50% flowable ureaformaldehyde (Fluf) applied at 98 and 244 kg N ha^{-1} yr^{-1}. Two irrigation regimes were used: one applied 1.2 cm of water when the tensiometer readings reached −0.05 MPa and the second was 3.75 cm water wk^{-1}. The former did not result in water draining out of the root zone, but the latter did. Drainage water was collected and analyzed for NH_4^+ and NO_3^-. Irrigation based on tensiometer reading did not cause a significantly ($P \leq 0.05$) higher mean annual N concentration in the drainage water at either rate of N applied than was found in the unfertilized control plots. However, irrigating at a higher rate resulted in significantly higher N concentrations in the drainage water (1.8 and 4.0 mg L^{-1} for the low and high N rates, respectively). These values are still well below safe drinking water standards of 10 mg NO_3-N L^{-1}.

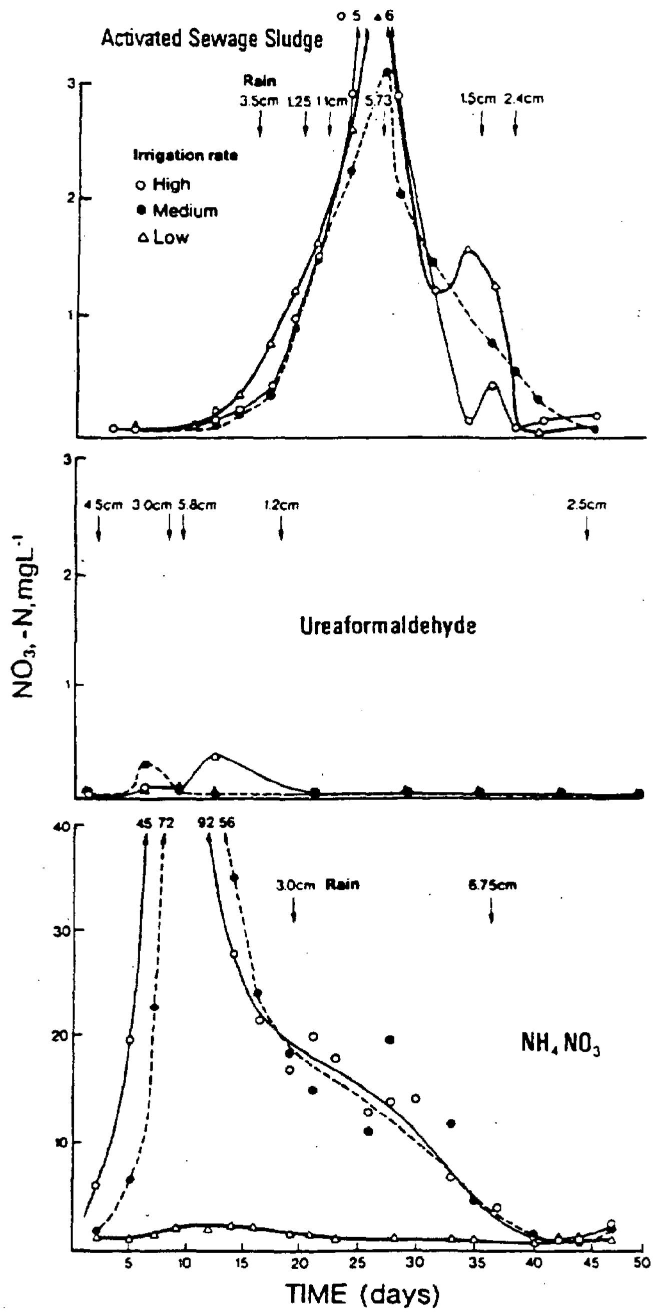

Fig. 5. Leachate concentration of NO_3-N as a function of N source and irrigation (low, medium, high): Milorganite applied on 17 Oct. 1973 at a rate of 146 kg N ha^{-1}, ureaformaldehyde applied on 6 June 1973 at a rate of 244 kg N ha^{-1}; NH_4NO_3 applied on 16 Feb. 1973 at a rate of 163 kg N ha^{-1} (with permission from Brown et al., 1977).

Snyder et al. (1984) studied the interactive effect of irrigation and N source on seasonal N leaching from sand under bermudagrass. Ammonium nitrate and SCU were applied at a rate of 98 kg N ha^{-1} to plots that were irrigated either on a fixed daily schedule or by tensiometer-activated irrigation (sensor). In addition, N was also applied in the irrigation water (fertigation). Soil water samples were extracted daily to determine the amount of N (NH_4^+ + NO_3^-) leaching past the root zone. The percent of applied N leached ranged from 0.3 to 56% and was highly influenced by N source, irrigation schedule, and season of the year. The greatest leaching occurred in the February and March period, less in April and May, and the least in the June and July. The decline in leaching loss was probably due to both increased plant growth and increased evapotranspiration. In every case, N leached from the daily-irrigated plots was 2 to 28 times greater than that leached from the sensor-irrigated plots. Generally, N leached from plots treated with NH_4NO_3 was from 2 to 3.6 times greater than that leached from ones treated with SCU. Generally, fertigation resulted in lowest N leaching losses, except for the June and July period.

Brown et al. (1977) also evaluated the effect of N source and rate of irrigation on NO_3^- leaching. Irrigation had little effect on NO_3^- leaching from plots treated with very high rates of N (146–244 kg ha^{-1}) from either activated sewage sludge or ureaformaldehyde (Fig. 5). In fact, NO_3^- concentration in the drainage water never exceeded the safe drinking water standard. However, when NH_4NO_3 was applied at the extremely high single application rate of 163 kg N ha^{-1}, medium to heavy irrigation (0.8–1.2 cm d^{-1}) resulted in substantial increases in NO_3^- concentration in the drainage water 5 to 30 DAT. Drainage water from greens irrigated with less than 0.8 cm d^{-1} (low) did not have elevated NO_3^- concentrations.

In a 10-wk growth chamber study, Mosdell and Schmidt (1985) determined the N leaching by collecting drainage water from pots of Kentucky bluegrass containing a silt loam soil. They applied 74 kg N ha^{-1} as either NH_4NO_3 or IBDU and irrigated the pots at 2.5 and 5.0 cm wk^{-1}. At cool temperatures, (16 °C/4 °C), the only treatment with high N concentration in the drainage water was IBDU irrigated at 2.5 cm wk^{-1}. Correcting for the leaching from the unfertilized check, this would amount to 2.7% of the applied N being leached. At a higher temperature regime (30 °C/24 °C), leaching of N from the NH_4NO_3 and IBDU pots occurred, but never in excess of 2.5% of applied N. Leaching was not influenced by irrigation amount.

The season at which the N is applied can have a direct effect on the amount of N that is leached. Leaching is significant during periods when temperature is low and precipitation (minus potential evapotranspiration) is high, e.g., November through April in northern climates. The cool temperatures reduce denitrification and NH_3 volatilization, limit microbial immobilization of N in the soil and limit plant uptake. However, low temperatures also reduce the rate of nitrification. With low evapotranspiration by plants and relatively high precipitation, more water drains out of the root zone.

The late fall has become an important time for N fertilization of cool-season grasses (Street, 1988). However, as stated above, this period may lead to a greater potential of NO_3^- leaching. This concept was tested in a cool season turfgrass study on Long Island, NY. Nitrogen was applied at 97 kg ha^{-1} in November (Petrovic et al., 1986). The amount of N leached out of the root zone (30 cm deep) was determined by trapping the NO_3^- with an anion exchange resin. The researchers found, as expected, that significant NO_3^- leaching can occur when a soluble N source like urea is used. Nitrate leaching ranged from 21 to 47% of applied N for urea, depending on the site characterics. On the site with a gravely sand B horizon, there was more NO_3^- leaching from urea. Losses from activated sewage sludge (Milorganite), ureaformaldehyde, and a resin coated urea, were less than 2% of applied N, whereas, NO_3^- leaching from plots treated with a nonsealed SCU was 12% of applied N. Even though the late fall N fertilization principle has many good agronomic benefits, the environmental impact may overshadow the positive factors in groundwater sensitive areas. Nitrate losses were also greater on warm-season grasses fertilized in the cooler periods of the year (February or March) compared with warmer seasons (Brown et al., 1977; Synder et al., 1984).

Runoff

When fertilizer N is applied to any site, there is a potential for some of it to run off into surface waters. A limited number of studies have been conducted to determine the quantity of fertilizer containing N that will run off a turfgrass site. In a 2-yr field study in Rhode Island, Morton et al. (1988) observed only two natural events that lead to runoff of any water. One was from frozen ground and the other occurred from wet soils receiving 12.5 cm of precipitation in one wk. The concentration of inorganic N (NH_4^+ + NO_3^-) in the runoff water from the two events ranged from 1.1 to 4.2 mg L^{-1}, far below the 10 mg L^{-1} drinking water standard. This amount, regardless of the treatment, accounted for less than 7% of the total N lost by leaching and run off.

Brown et al. (1977), studying the impact of N source, rate and soil texture, only found in one case (1-d period) that runoff water had NO_3^- concentrations in excess of 10 mg NO_3^--N L^{-1}.

Watschke (personal communication 1988), studying runoff from turf sites on a 9 to 12% slope, silt loam soil, also observed only one natural precipitation event that led to runoff over 2 yr of the study. Results of these studies suggest that the turfgrass ecosystem results in soils with high infiltration capacity; thus, runoff seldom occurs.

SUMMARY AND CONCLUSION

The distribution of fertilizer N applied to turfgrass has generally been studied as a series of components rather than a complete system. Only Starr and DeRoo (1981) attempted to study the entire system of the fate of N applied to turfgrass. However, their findings are limited to a small set of conditions (i.e., cool-season turfgrass, unirrigated, sandy loam soil). Thus, more information of this nature is needed on a wide range of conditions.

Generally, the amount of fertilizer N recovered in the turfgrass plant (clippings, shoots, and roots) varied from 5 to 74%, depending on factors such as N source, rate and timing, species of grass, and other site-specific conditions. The highest recovery of total fertilizer N was noted for Kentucky bluegrass fertilized with a soluble N source at a moderate rate (102 kg ha^{-1} yr^{-1}) (Selleck et al., 1980). In contrast, the lowest recovery also occurred on Kentucky bluegrass fertilized with a very slowly available N source (Mosdell et al., 1987). When accounting for recycled fertilizer N in the returned clippings, Starr and DeRoo (1981) observed that about 29% of the fertilizer N was found in the turfgrass plant. Information on N recovery from warm-season grasses is lacking but very necessary to develop models that predict the fate of N applied to warm-season turfgrasses.

Atmospheric loss of fertilizer N can occur by NH_3 volatilization or denitrification. Ammonium volatilization losses can range from 0 to 36% of the applied N. Reducing NH_3 volatilization can be accomplished by irrigating the fertilizer into the soil (Bowman et al., 1987), by using slowly available N sources and reducing the amount of thatch present (Nelson et al., 1980).

Information on denitrification is limited. Losses can be substantial (93% of applied N) under conditions of a saturated silt soil at high temperatures (Mancino et al., 1988). However, more information is needed on a wider variety of site conditions (soil) and turfgrasses to more thoroughly understand the impact that denitrification has on the fate of N.

The storage of fertilizer N in the soil generally occurs in the soil organic matter phase or as undissolved fertilizer pellets of slow-release N sources (Hummel and Waddingtion, 1981). The actual amount of fertilizer found in the soil was determined by Starr and DeRoo (1981). They found that between 36 to 47% of the fertilizer N was in the soil-thatch pool.

Leaching of fertilizer N applied to turfgrass has been shown to be highly influenced by soil texture, N source, rate and timing, and irrigation/rainfall. Obviously, if a significantly higher than normal rate of a soluble N source is applied to a sandy turfgrass site that is highly irrigated, significant NO_3^- leaching could occur (Brown et al., 1977). However, limiting irrigation to only replace moisture used by the plant (Morton et al., 1988; Synder et al., 1984), using slow-release N sources (Brown et al., 1982; Petrovic et al., 1986; Synder et al., 1984) and using less sandy soils (Brown et al., 1977) will significantly reduce or eliminate

NO_3^- leaching from turfgrass sites. If turfgrass fertilization does pose a threat to groundwater quality, several management options are available to minimize or eliminate the problem.

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Appendix C.

Control Measures for Storm Water Runoff and Infiltrate

STORM WATER RUNOFF-RETENTION/DETENTION PONDS, RECONSTRUCTED WETLANDS

Detention and Retention Ponds

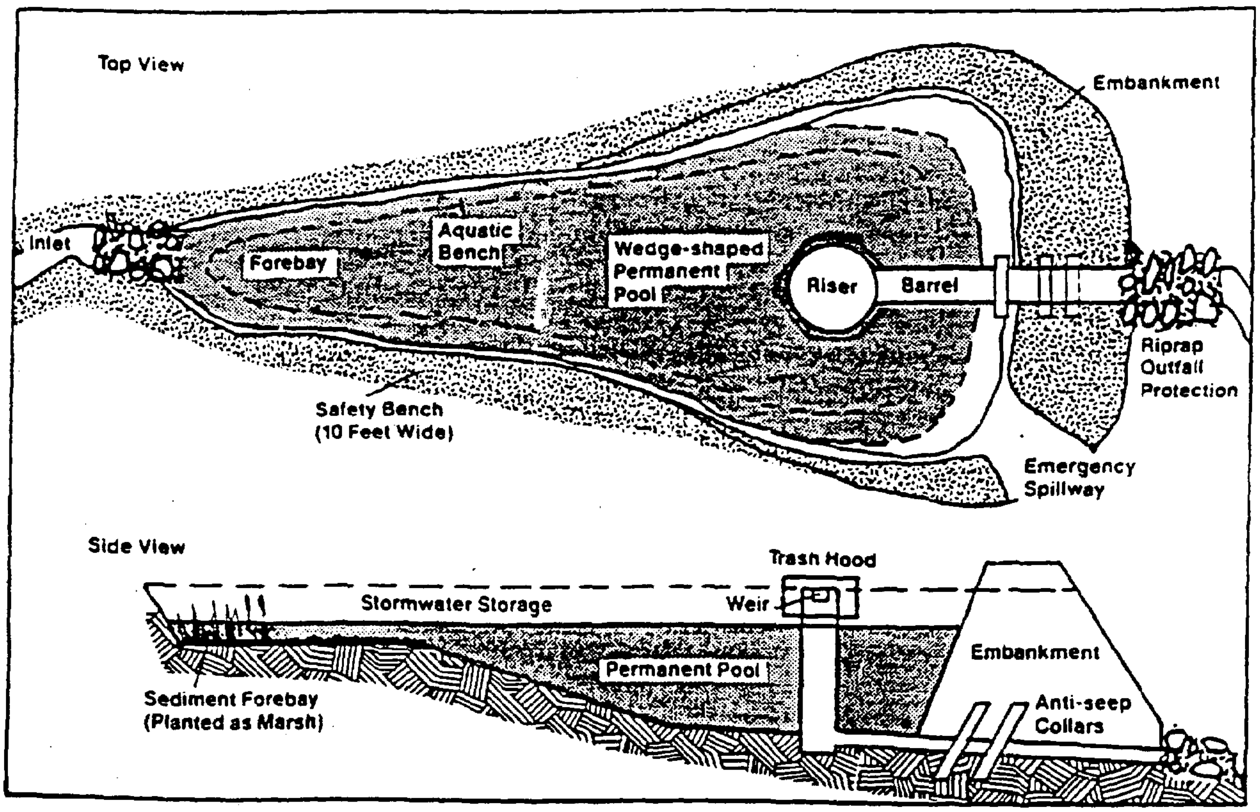
Detention and retention ponds are designed to hold runoff for extended period of time in order to reduce flooding, and to remove suspended solids (silts, etc.) and their associated pollutants (metals or organic compounds adsorbed to particulates).

Detention and retention ponds differ in the way that runoff is handled. Retention ponds are designed to capture and infiltrate runoff although some form of spillway is generally provided to handle large flood events. Detention ponds serve to detain and release runoff at a controlled rate. History has shown that if stormwater is detained for 24 hours or more, as much as 90% removal of pollutants is possible. Therefore, when using ponds for water quality benefits, extended runoff detention ponds or retention ponds should be provided. Ground water recharge is limited to the runoff which infiltrates through the pond bottom during the relatively infrequent times when the pond is flooded. While simple detention ponds are typically dry, extended detention ponds may be wet or dry. Figure 1 provides a schematic of a typical extended detention pond.

Another design consideration is to prevent resuspension of deposited materials by scouring basin sediments by incoming runoff. Retention ponds are generally "wet ponds" which retain a permanent pool and prevent resuspension of particulates by slowing incoming water with the existing pool (see Figure 2).

Retention and extended detention ponds are an effective water quality control measure. If properly designed and maintained, ponds are very effective in removing suspended solids and their associated compounds. Costs are site specific and vary considerably. In general, ponds cost between $15,000-$40,000. In cases where retention ponds are used, biological processes within the pond also remove soluble nutrients such as nitrate and ortho-phosphorus. Artificial wetlands may be created in association with extended detention ponds and retention ponds to provide further pollutant removal. Additional positive impacts of retention and detention ponds include the creation of local wildlife habitat and landscape amenities. Negative impacts include potential safety hazards, the need for regular maintenance and occasional nuisances such as algae, odor and debris.

FIGURE 2. SCHEMATIC OF WET POND



SOURCE: T.Schueler, 1987

Infiltration Basin

A typical infiltration basin, shown in Figure 3, is an effective BMP for removing fine particulates and dissolved materials. Infiltration basins trap and hold runoff until it percolates into the soil.

To function properly a site must have permeable soils and adequate (at least 2-4 feet) depths to bedrock and water table to allow percolation. When designing the basin, coarse particulates should be removed before allowing runoff to enter the basin to lessen clogging of soil pores. Using a combined detention-infiltration basin design which utilizes a modified riprap settling basin to trap coarse particulates is also an effective option. Design problems generally involve ensuring an even spread of flow over the basin floor; and handling a variety of storm intensities. A variety of design modifications exist to accommodate these problems (see Schueler, 1987 for further information).

Construction and maintenance costs for infiltration basins are slightly more than those for extended detention ponds, owing to the need to encourage infiltration. The primary disadvantages for their use include the need for high permeability soils, a backup drainage system in case of infiltration failure, failure due to soil freezing, and the potential danger of ground water contamination when used near public and private water supply wells.

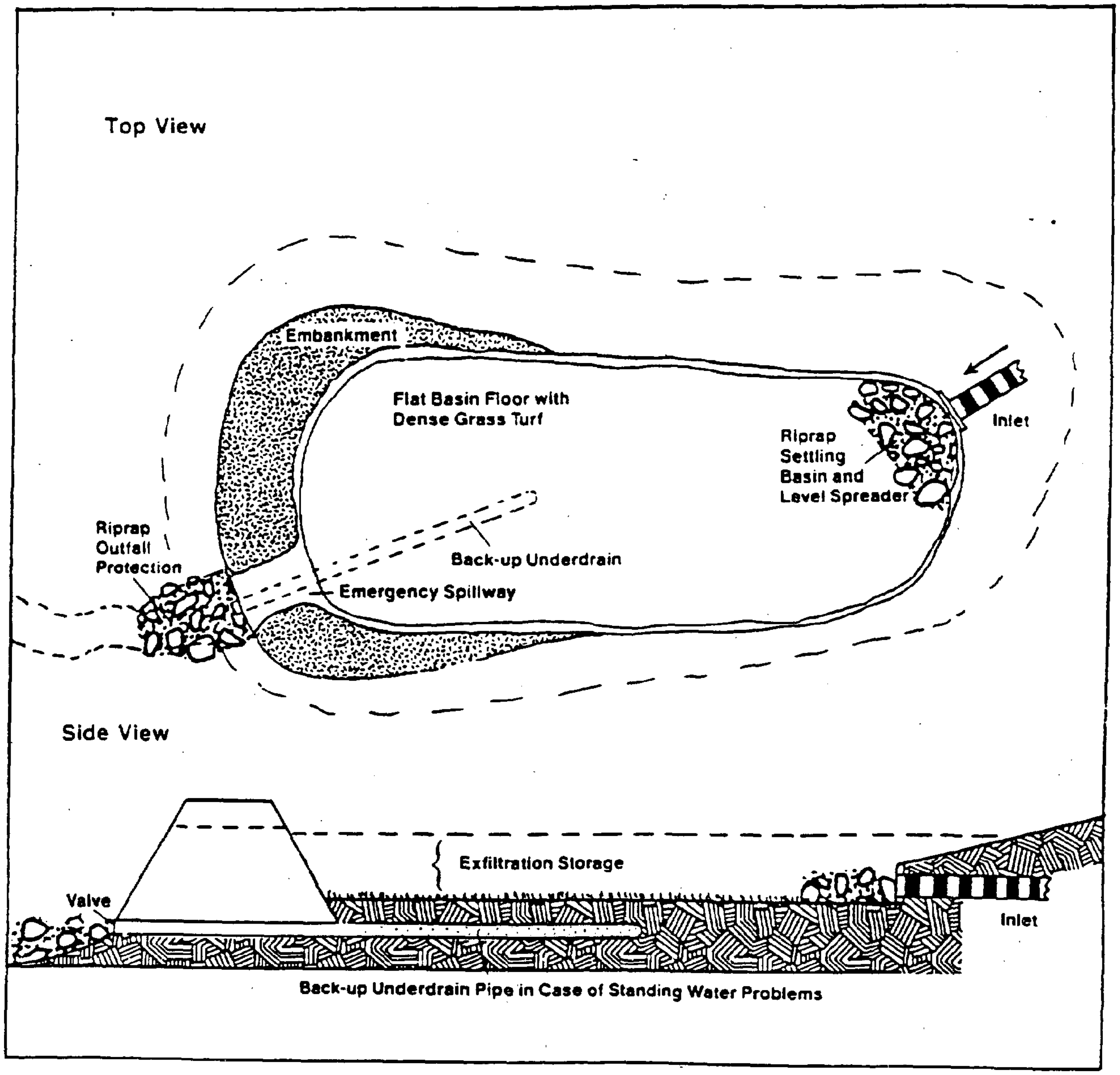
Infiltration Trench

Figure 4 presents a schematic of an infiltration trench. As for infiltration basins, trenches will quickly clog unless coarse sediments are removed from runoff prior to entering the trench. They are effective in removing fine suspended particles and dissolved pollutants. Infiltration trenches are a very flexible BMP because they can be tailored to a wide variety of runoff control situations.

Infiltration trenches can be a desirable option for reducing runoff-borne pollution from parking lots and roadways because of their minimal space requirements, easy construction and relatively low cost. Figures 5-7 show several differert trench system.

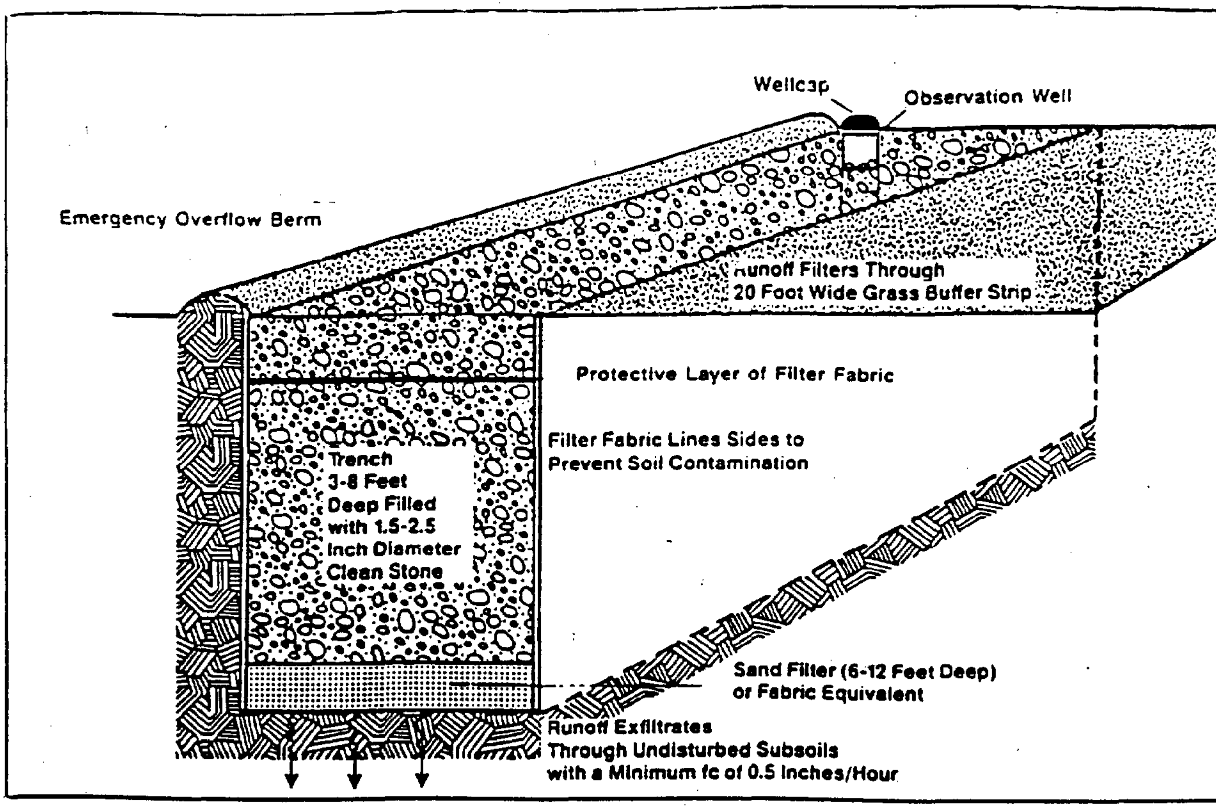
Maintenance requirements and costs are generally low to moderate, but as for all infiltration structures, proper maintenance is essential for good performance. Disadvantages include need for high permeability soils and high cost for large scale runoff control situations (>10 acres).

FIGURE 3. SCHEMATIC OF INFILTRATION BASIN



SOURCE: T.Schueler, 1987

FIGURE 4. SCHEMATIC OF INFILTRATION TRENCH



SOURCE: T.Schueler, 1987

FIGURE 5. SCHEMATIC OF MEDIAN STRIP TRENCH

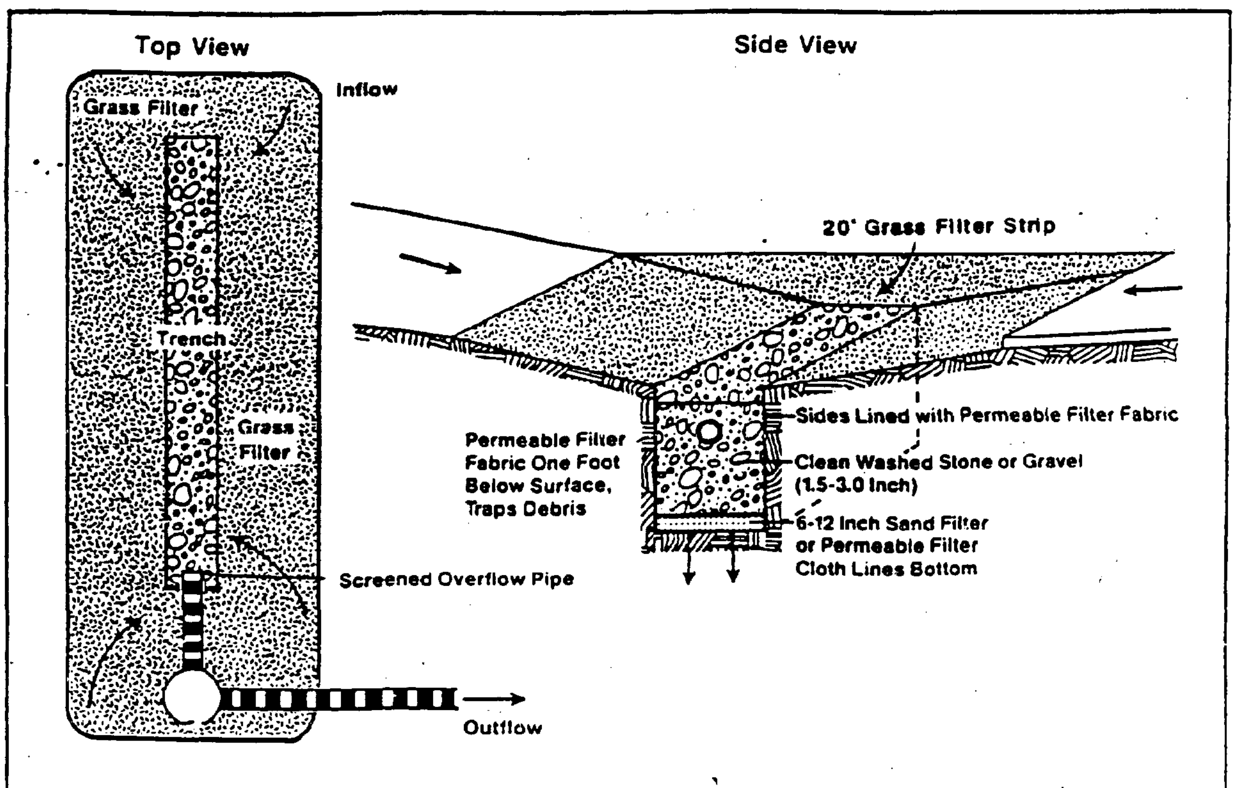
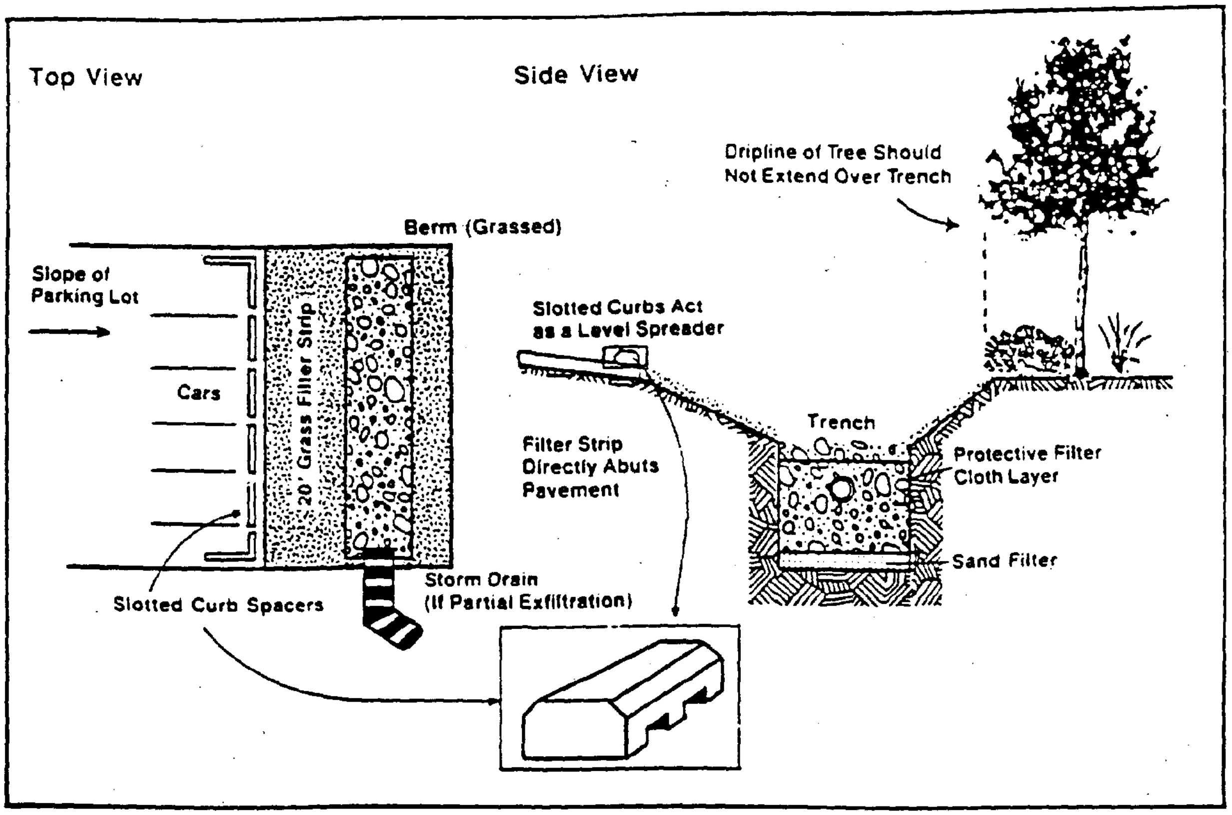
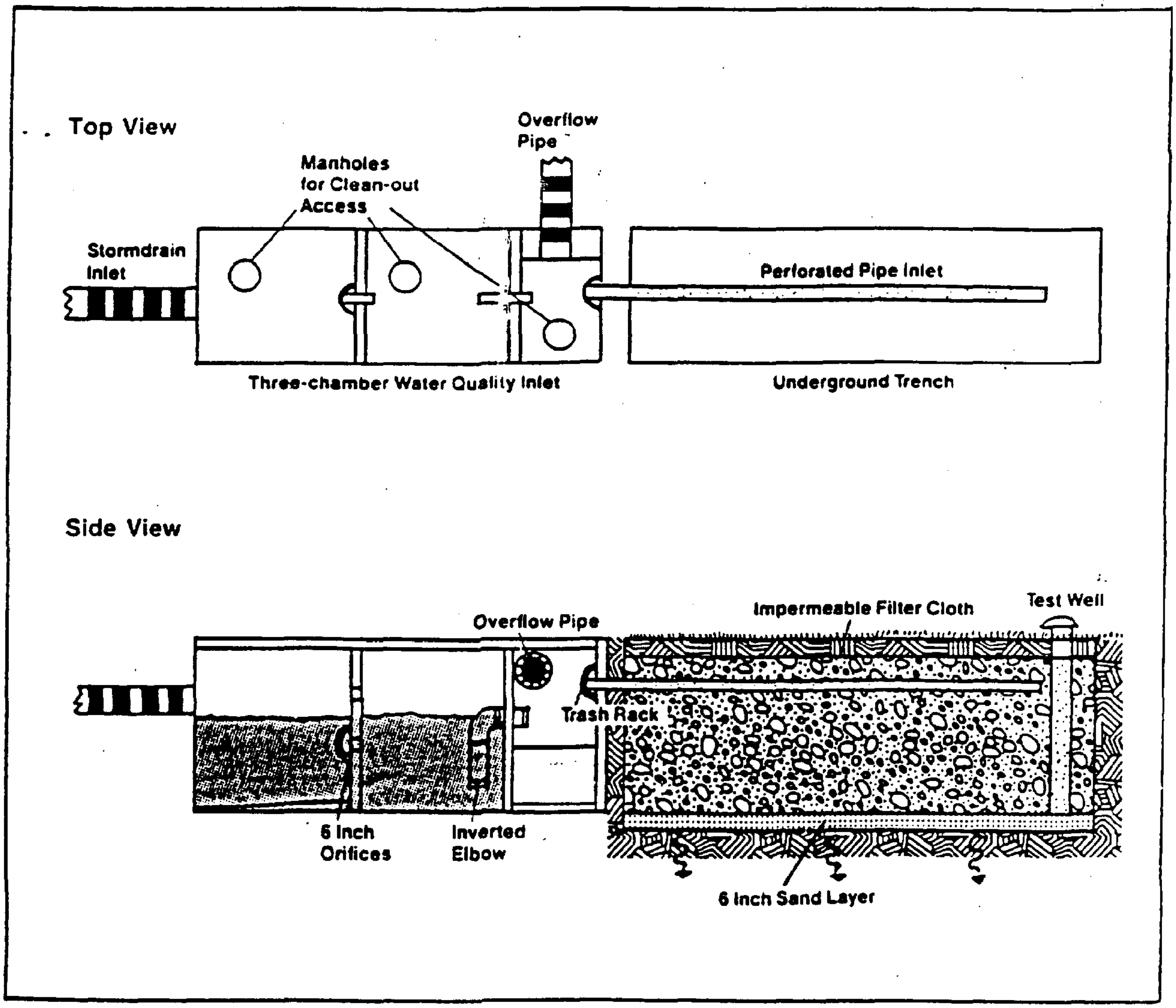


FIGURE 6. SCHEMATIC OF PARKING LOT TRENCH



SOURCE: T.Schueler, 1987

FIGURE 7. SCHEMATIC OF UNDERGROUND TRENCH WITH OIL/GRIT CHAMBER



SOURCE: T.Schueler, 1987

Porous Pavement

Porous pavements, if constructed correctly, can eliminate any need for further pollution treatment because they act to infiltrate precipitation into the ground before it has a chance to become surface run-off. As shown in Figure 8, the pavement must be constructed over permeable soils and are limited to gentle slopes to prevent run-off. However, it can remove both suspended and dissolved pollutants.

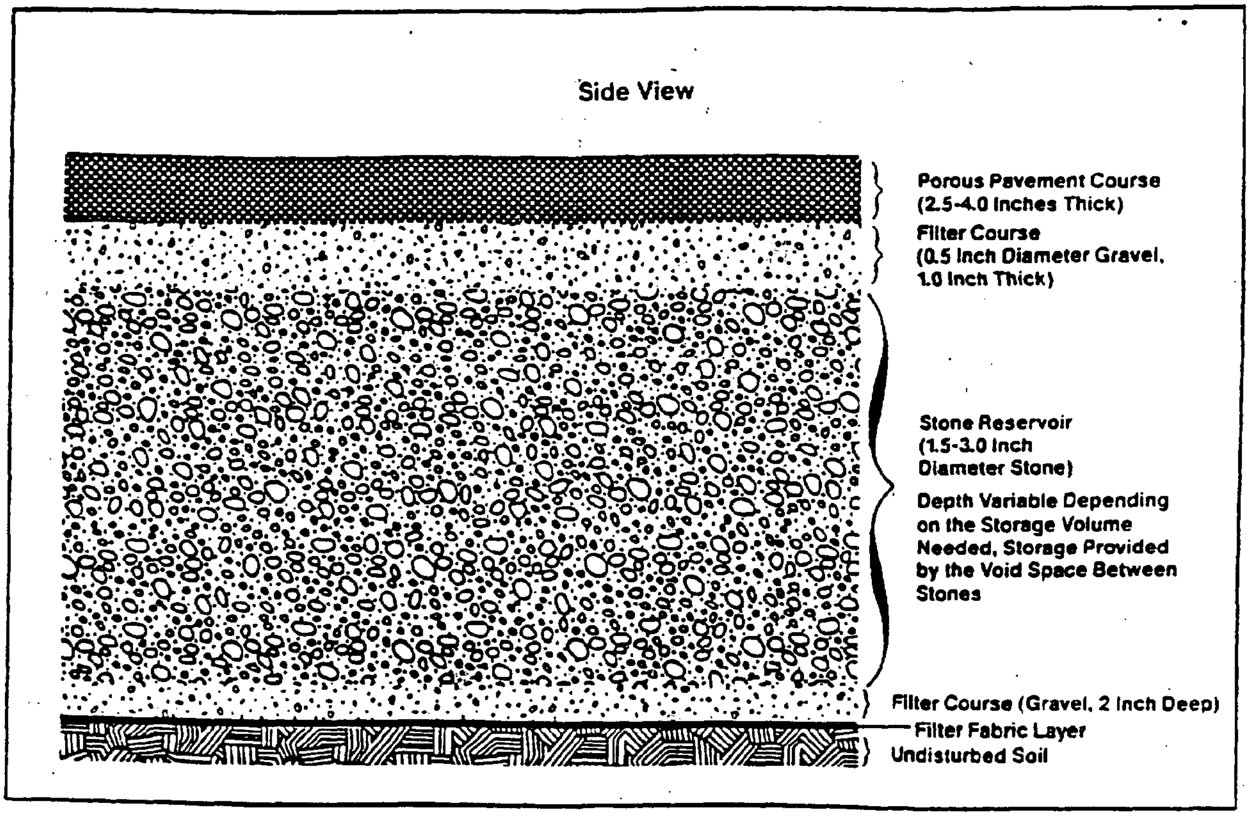
The major disadvantages of porous pavements are the need to prevent clogging from sediments carried onto the pavement, the tendency toward cracking due to freeze and thaw periods. The pavements are liable to clog if the roadway receives any eroded soil or sediments from the surrounding watershed. Likewise, it is unclear whether this pavement is a viable long-term option in the northeast due to its susceptibility for cracking due to winter cold. While the use of porous pavement offers many advantages: reduced land requirements, little or no need for curbs and gutters, and ease of maintenance, further research is needed to evaluate their use in the northeast.

Grassed Swales

Grassed swales (Figure 9) are constructed, grass-lined channels that utilize flat slopes or grasses to direct runoff and remove particulates. In many cases, grassed swales serve as an alternative to standard curb-gutter drainage systems since they are generally less expensive and allow at least some stormwater infiltration and pollutant removal on site. Swales aid to control peak discharges through reducing run-off velocities and allowing infiltration. However, the volume of infiltration is generally small. Grassed swales are capable of removing particulates from run-off, however, they are not effective in removing dissolved pollutants. Due to their limited capacity to provide infiltration and pollutant removal, grass swales are generally used in conjunction with additional run-off control measures for large developments.

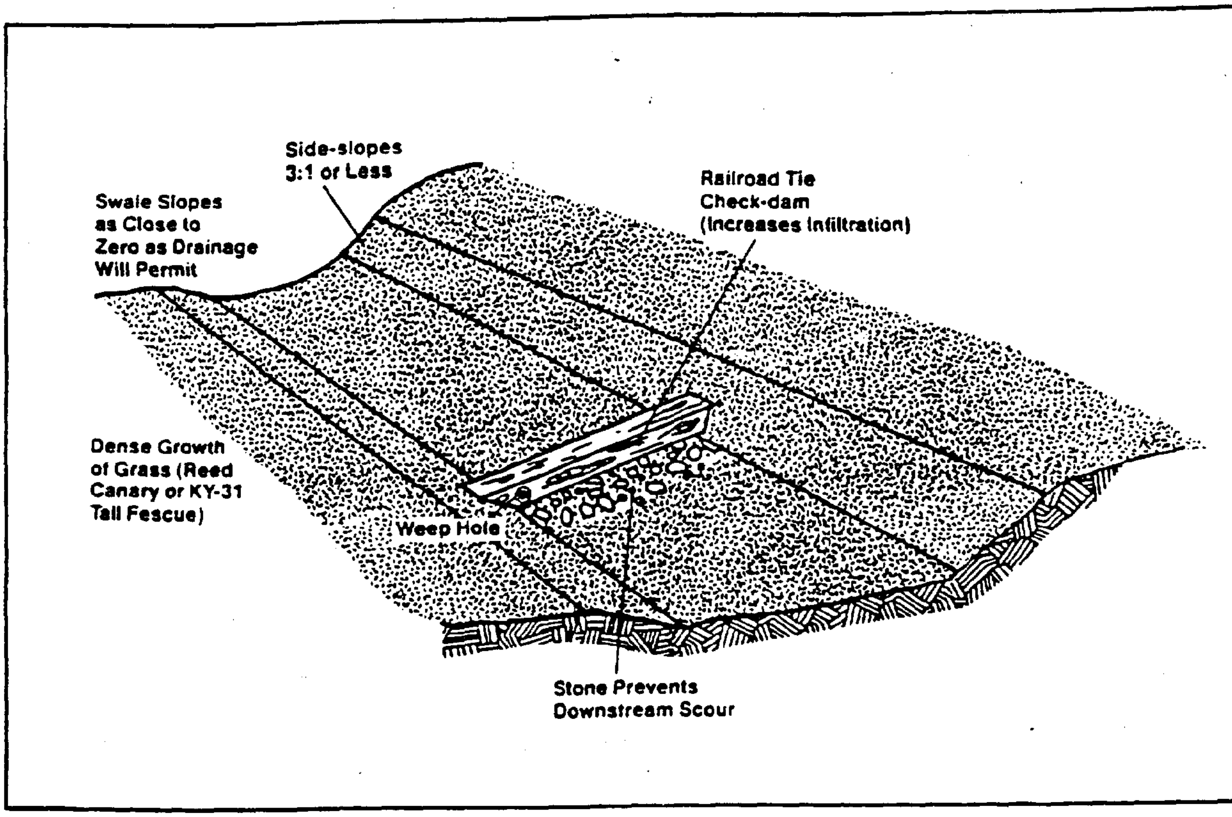
Grassed swales can be very effective in reducing soil erosion because, if properly designed, the grass and gentle slopes slow down runoff flow velocities. They are much less costly in both construction and maintenance costs than curb-gutter drainage systems. Care must be taken not to use large amounts of fertilizers or pesticides to maintain grass cover because they can end up being carried directly into the receiving body of water by storm runoff.

FIGURE 8. SCHEMATIC OF POROUS PAVEMENT



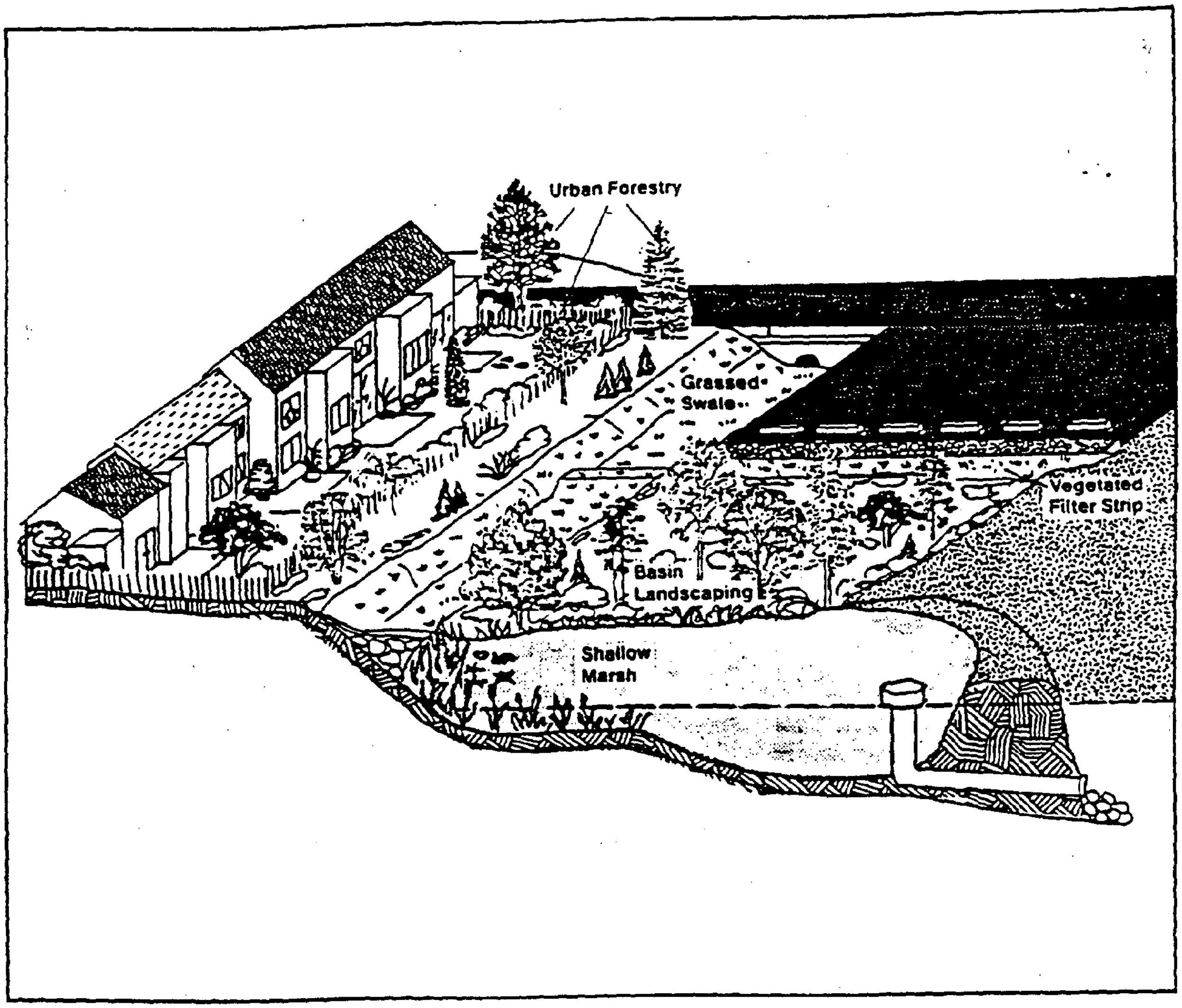
SOURCE: T.Schueler, 1987

FIGURE 9. SCHEMATIC OF GRASSED SWALE



SOURCE: T.Schueler, 1987

FIGURE 10. SCHEMATIC OF CONSTRUCTED WETLAND



SOURCE: T.Schueler, 1987

Constructed Wetlands

Wetlands are generally constructed on-site as an extension to retention and detention ponds (Figure 10). When properly designed and constructed, man-made wetlands mimic a natural wetland's ability to remove large amounts of dissolved and suspended materials from runoff flow. Constructed wetlands are generally very successful at handling stormwater run-off generated on-site, but are expensive to construct and maintain.

A summary of the pollution reduction benefits of various runoff control structures is provided in Chapter 2 of the book, "Controlling Urban Run-off: A Practical Manual for Planning and Designing Urban BMPs" by Thomas Schueler, Department of Environmental Programs, Metropolitan Washington Council of Governments. A copy of this section is included in this course manual.

Wastewater

Septic systems are often a source of water pollution. Sewage effluent may enter lakes through ground water or surface water run-off. In lakes where groundwater represents a significant amount of water input, sewage from properly functioning septic systems may be a significant source of nutrient loading. If septic systems are not maintained, such that that it fails and sewage backs up at the land surface, effluent may travel in overland run-off, conveying nutrients, bacteria and viruses to the lake system. DEM staff may control nutrient loading from septic systems through their proper siting and maintenance.

REFERENCES

Cohen, S.Z., S. Nickerson, R. Maxey, A, Dupuy, and J.A. Senita. 1990. A ground water monitoring study for pesticides and nitrates associated with golf courses on Cape Cod. Ground Water Monitoring Review. 10 # 1: 160-173.

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Schueler, T.R. 1987. Controlling urban runoff: a practical manual for planning and designing urban BMPs. Metropolitan Washington Council of Governments.

Synder, G.H., B.J., Augustin, and J.M. Davison. 1984. Moisture sensor-controlled irrigation for reducing N leaching in Bermuda-grass turf. Agron. J. 76:964-969.

Fig. 5 WATER QUALITY MANAGEMENT

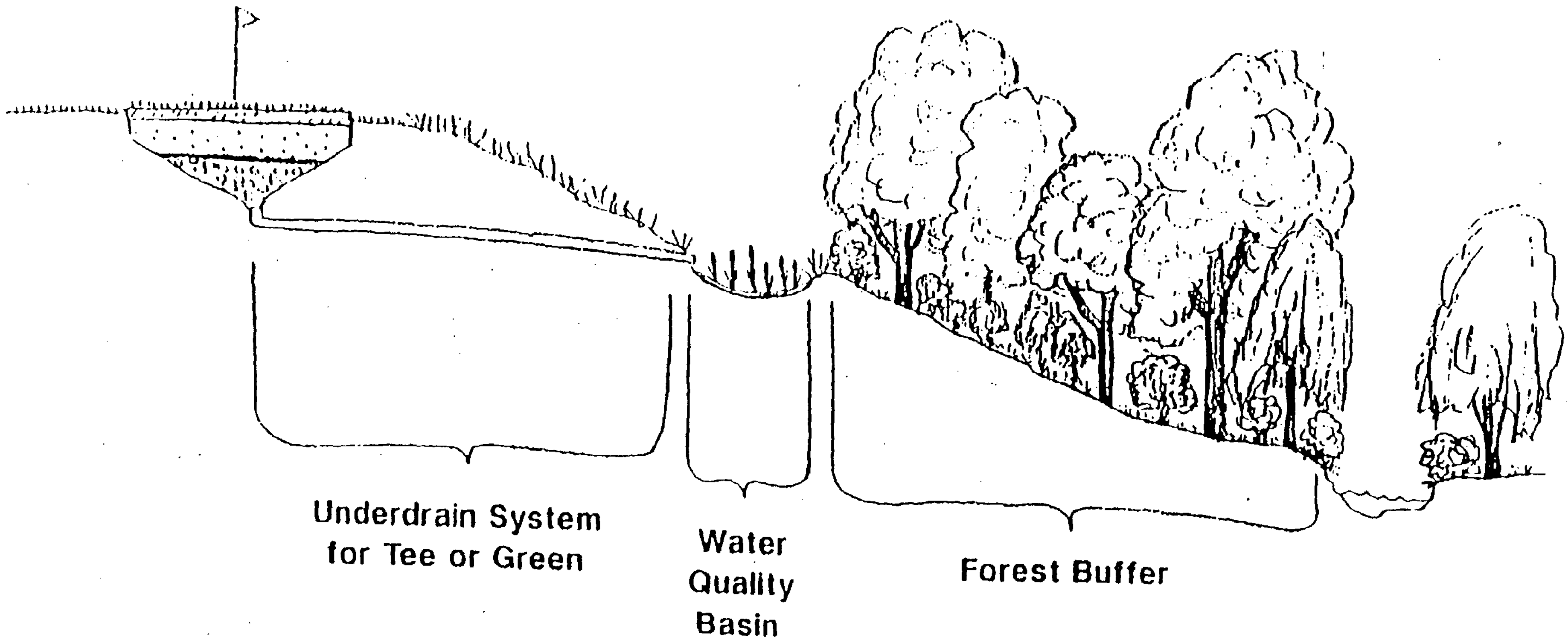


Fig. 6 WATER QUALITY MANAGEMENT

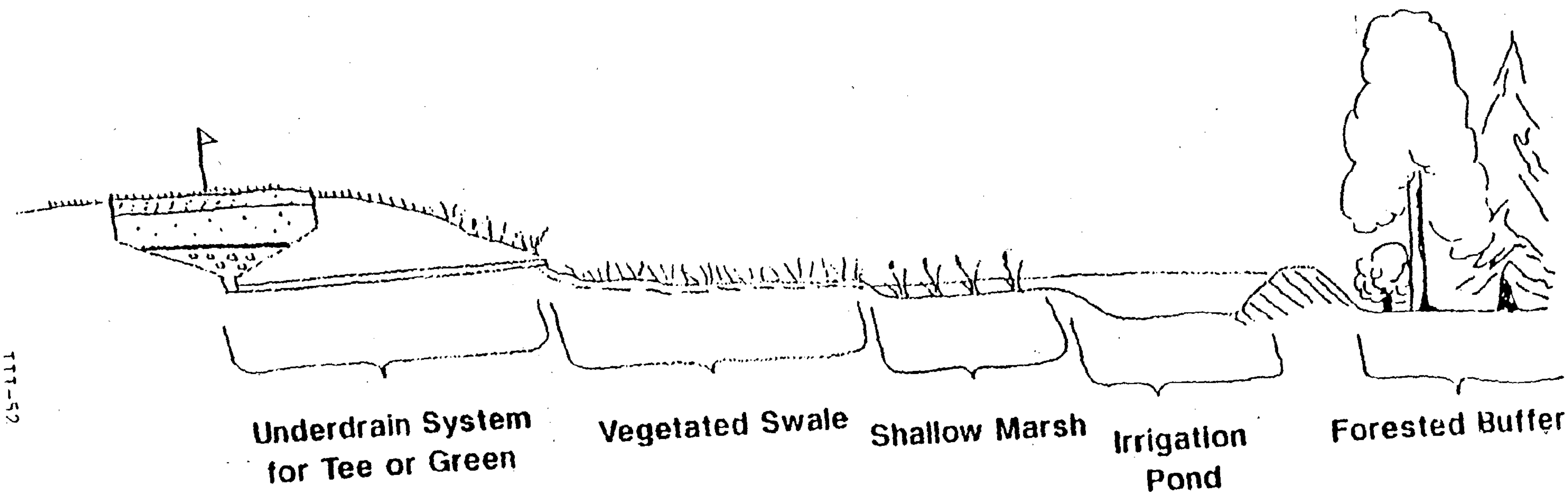
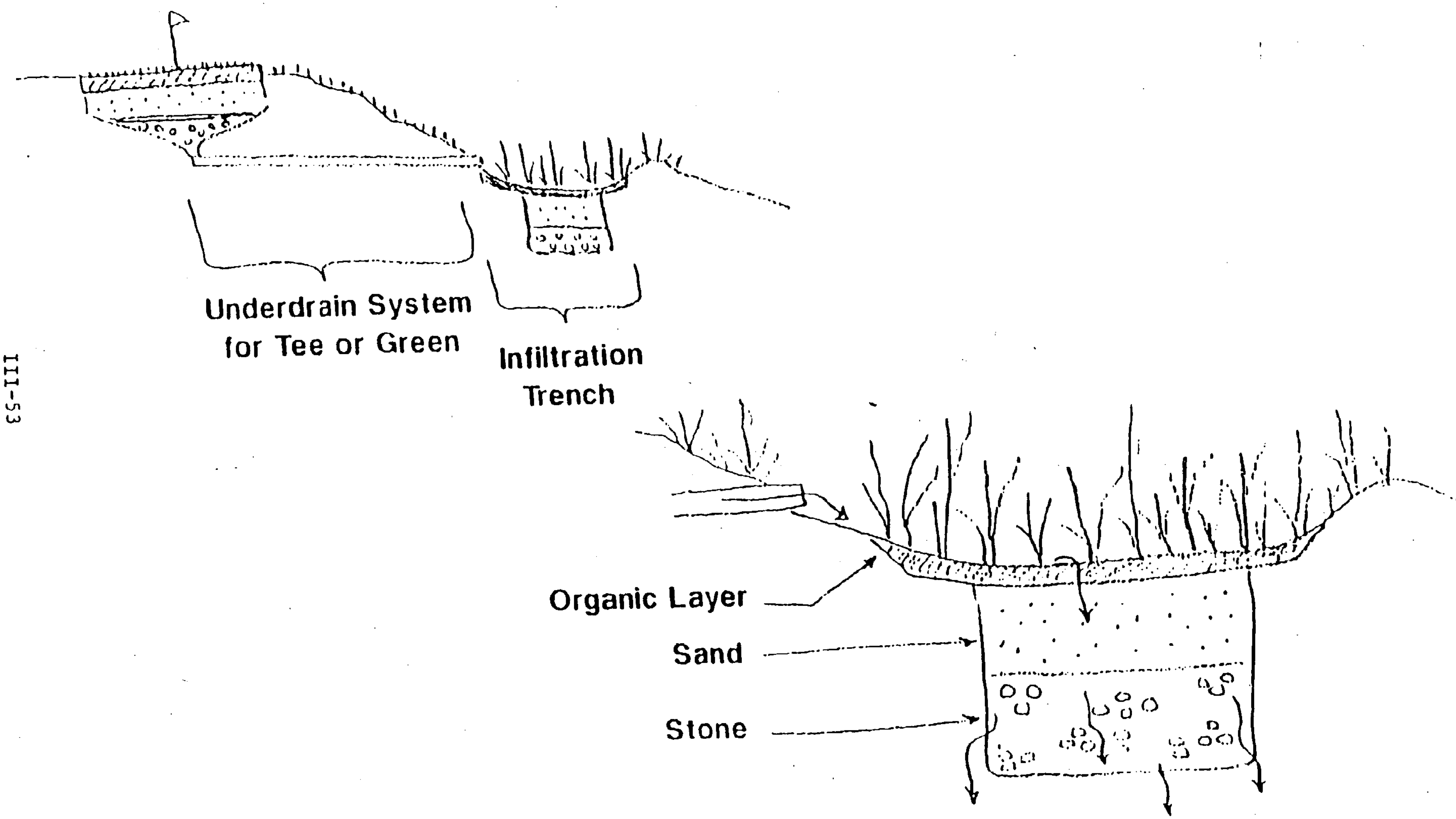


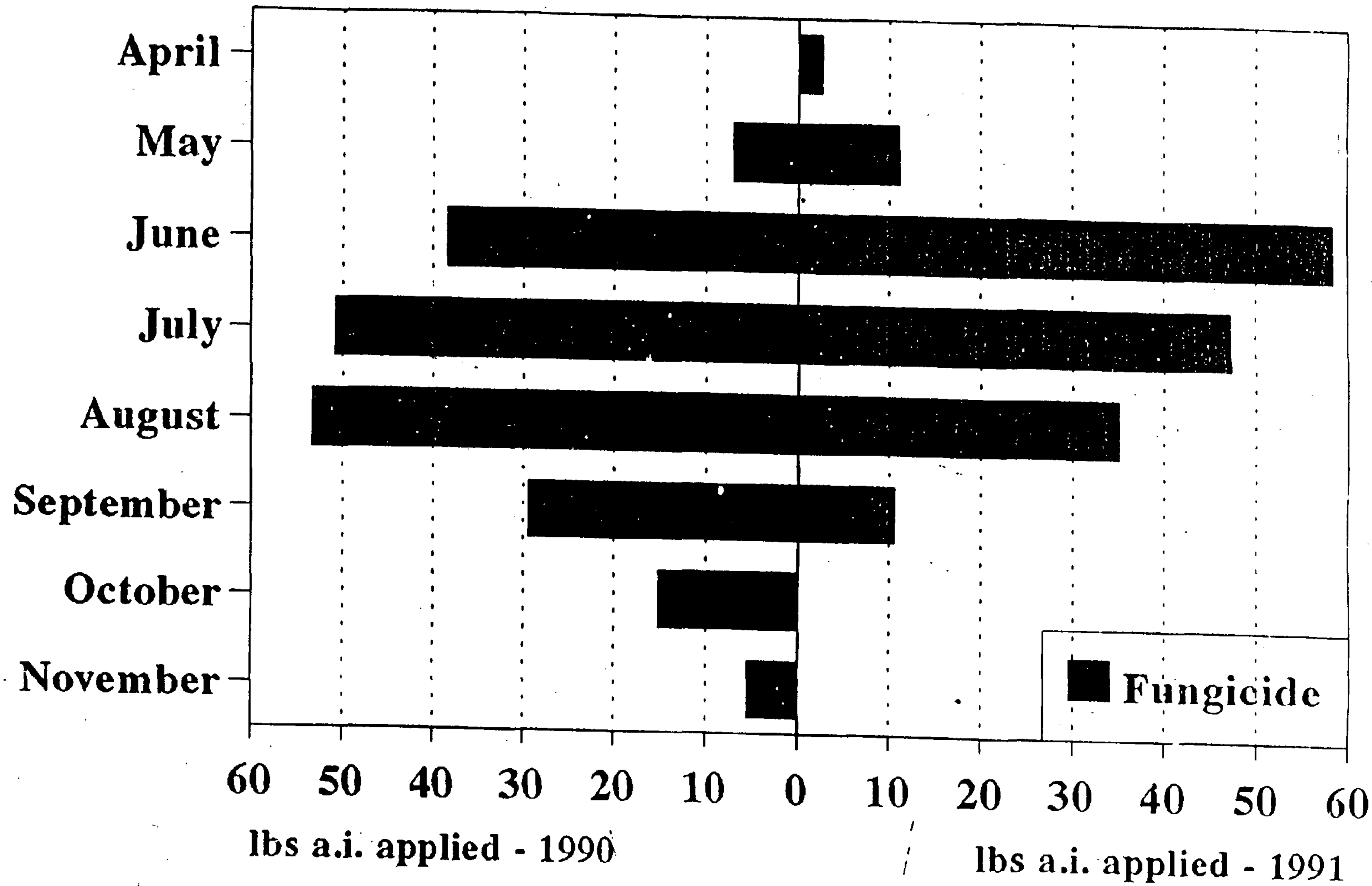
Fig. 7 WATER QUALITY MANAGEMENT



Appendix D.

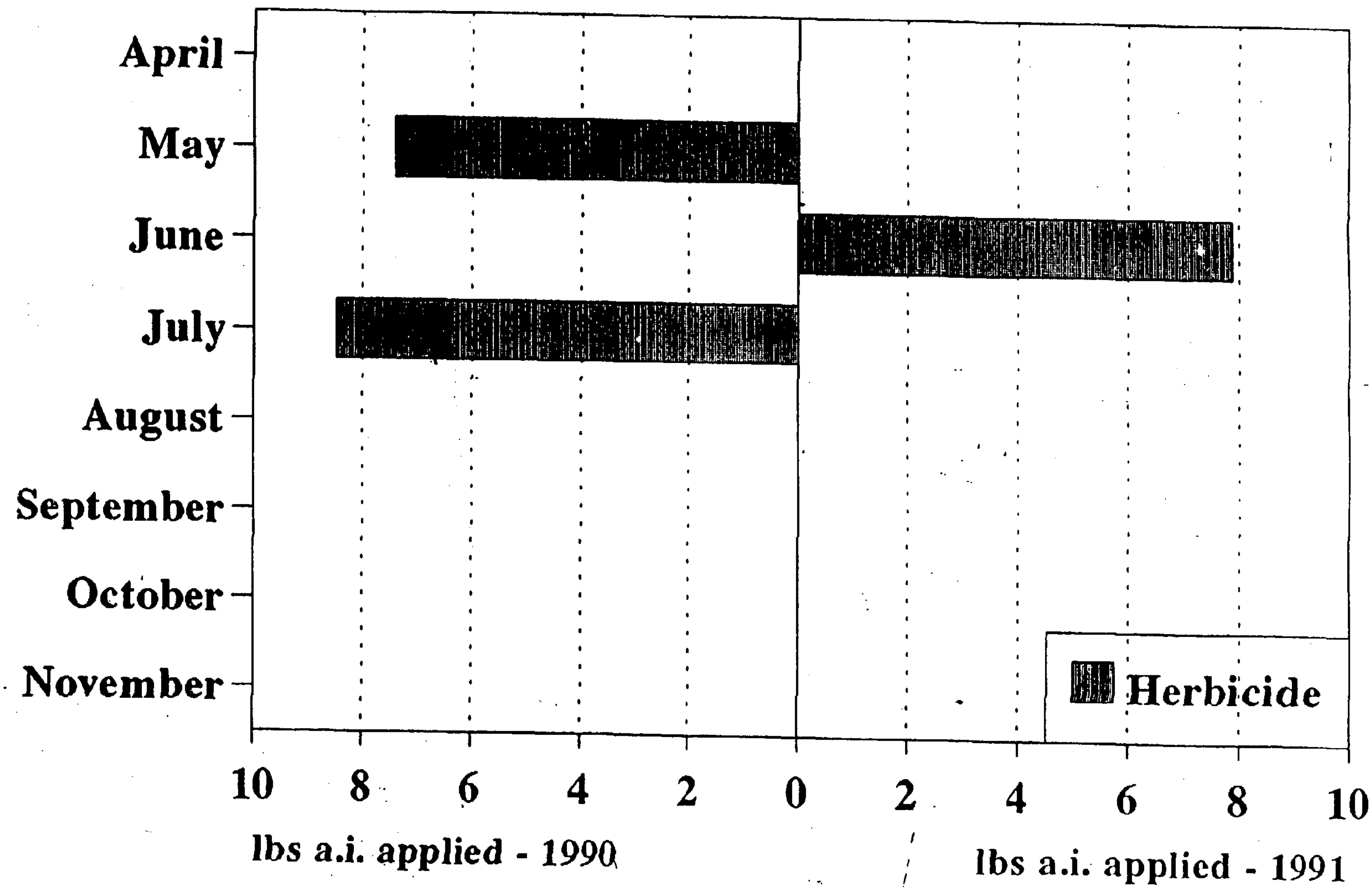
Pesticide Use on Golf Courses at a Representative Golf Course in New Jersey and NJDEPE Laboratory Routine Capability for Pesticide Analysis

Pesticide Use



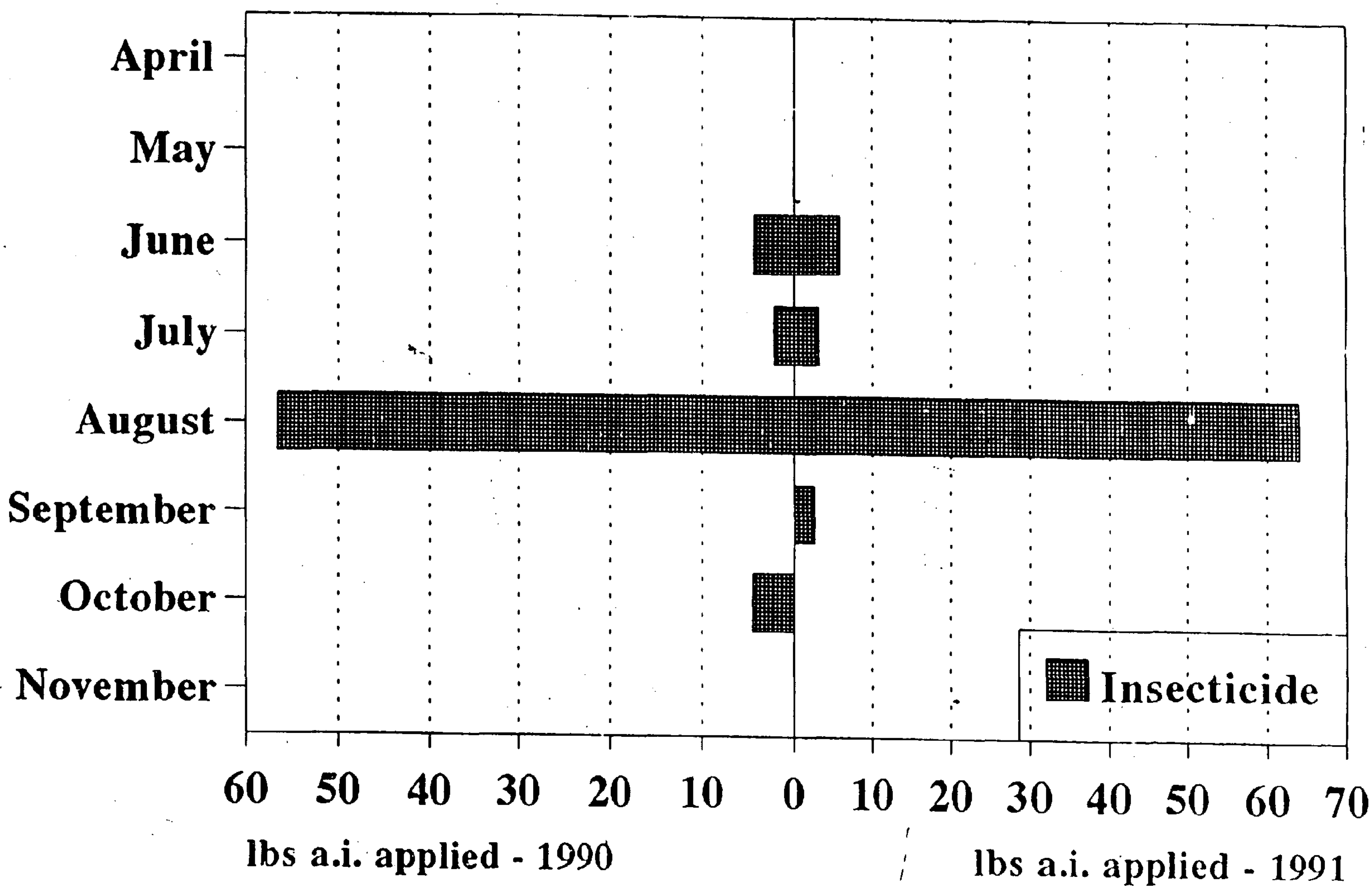
ıtal acreage = 226
ɔurse acreage = 100

ʀesticide Use

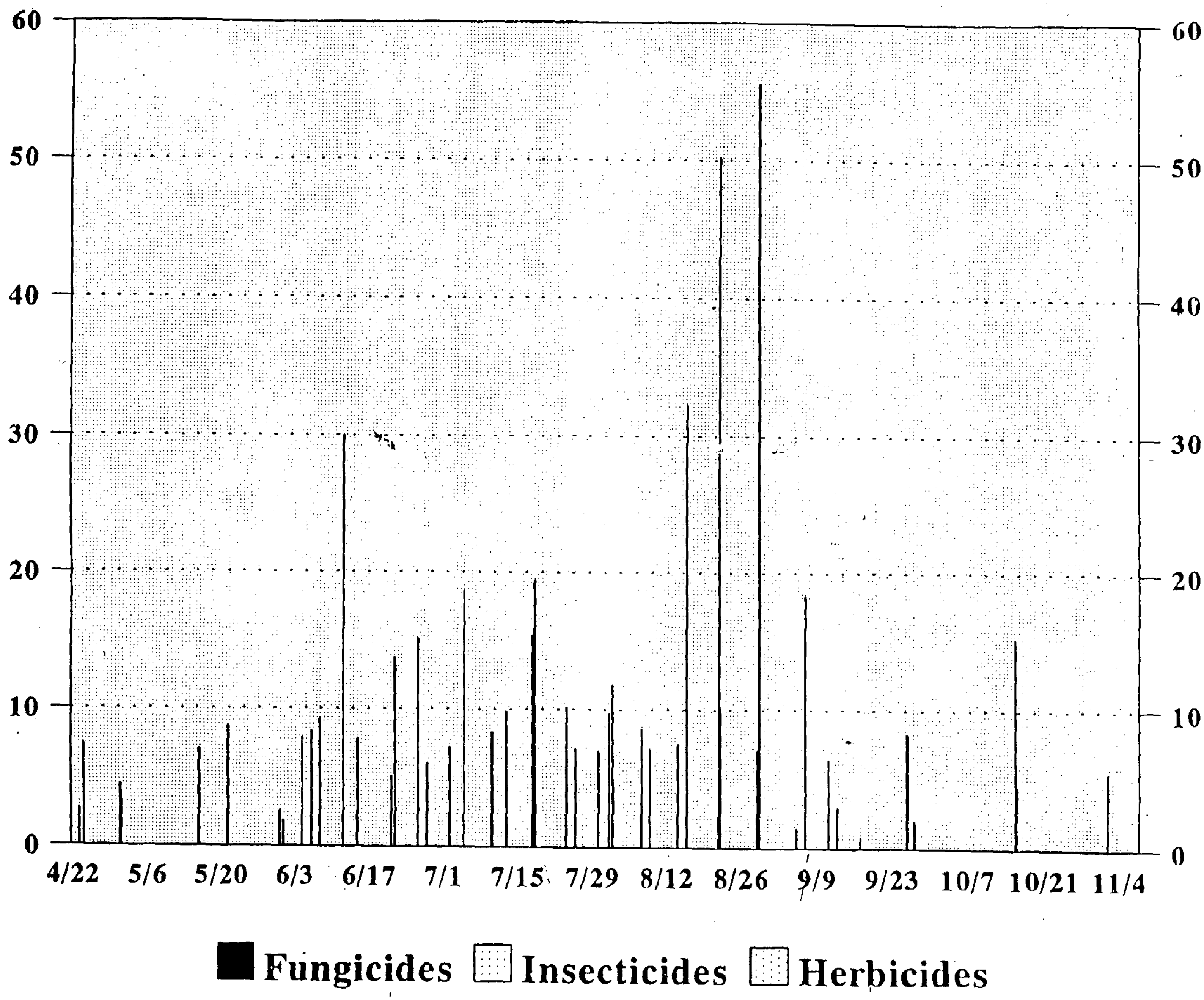


'otal acreage = 226
:ourse acreage = 100

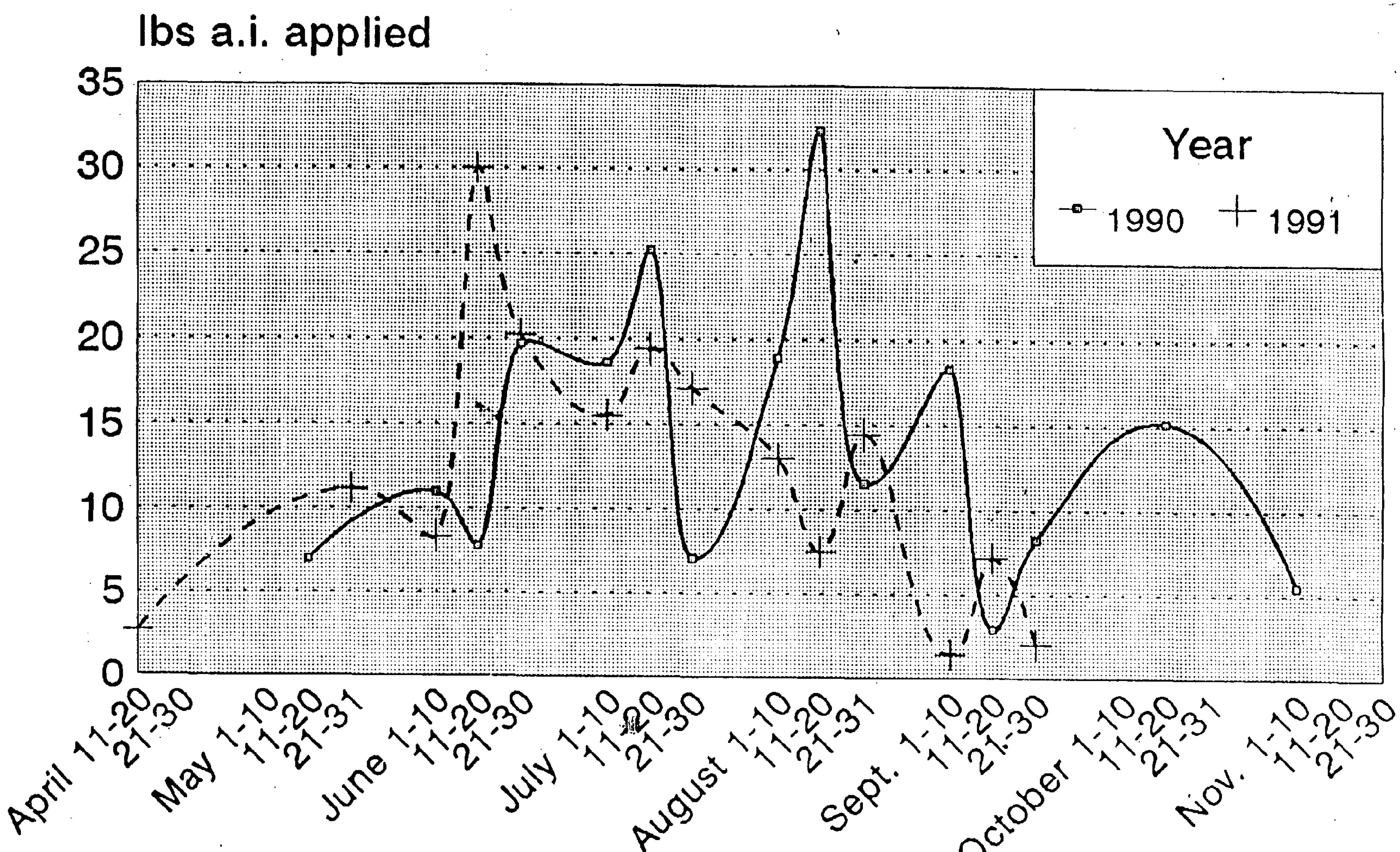
Pesticide Use



al acreage = 226
ırse acreage = 100


60
50
40
30
20
10
0
4/22
5/6
5/20
6/3
6/17
7/1
7/15
7/29
8/12
8/26
9/9
9/23
10/7
10/21
11/4
Fungicides
Insecticides
Herbicides

Fungicide Use



Atlantic Co.
Representive golf course

SOP APPENDIX   NJDEPE LABORATORY ROUTINE CAPABILITY FOR PESTICIDE ANALYSIS   UPDATED 8/1/92 (PCP/TEAM/AMW)

PCP CODE	PESTICIDE Common Chemical Name	SAMPLE MATRIX Swab	Water	Soil	Air	Other	EXTRACTION SOLVENT	TRADENAME / SYNONYMS	STABILITY / STABLE pH RANGE
40	2,4,5-T	SWAB	WATER	SOIL		FORM	MeCl2/ACID		pH 2
41	2,4,5-TP (SILVEX)	SWAB	WATER	SOIL		FORM	MeCl2/ACID	SILVEX	pH 2
39	2,4-D	SWAB	WATER	SOIL		FORM	MeCl2/ACID	ESTERON;DACAMINE;WEEDONE	
44	2,4-DB (DICHLORPROP)	SWAB	WATER	SOIL		FORM	MeCl2/ACID	BUTYRAC	pH 6-7ester
9	ACEPHATE	SWAB	WATER	SOIL			HEXANE	ORTHENE;TORNADO;PT-1300	pH 7
47	ALACHLOR	SWAB	WATER				ACETONE/MeCl2	ARENA,LASSO,LAZO,ALANEX	
22	ALDICARB	SWAB	WATER	SOIL		FORM	METHANOL or PCP	TEMIK	pH 3-6
29	ALDRIN	SWAB	WATER	SOIL			HEXANE	TERMINIX A-4	pH 5-7
35	ALLETHRIN	SWAB					HEXANE *	PYNAMIN	pH 4-6
97	ARSENIC (INORGANIC)						AA / ICP	ARSENIC	
55	ATRAZINE	SWAB	WATER	SOIL			METHANOL*/MeCl2	AATREX;PRIMATOL;ATRATOL	pH 7
7	AZINPHOS-METHYL (GUTHION)	SWAB	WATER	SOIL			HEXANE	GUTHION	pH 7
19	BENDIOCARB	SWAB	WATER	SOIL			METHANOL OR PCP	FICAM; DYCARB; TURCAM	pH 7******
95	BENFLURALIN	SWAB						BENEFIN; BENFLURALIN; TEAM* (52)	
48	BENOMYL	SWAB		SOIL		FORM	ACETONITRILE	BENLATE; TERSAN 1991;	pH 7******
110	BENSULIDE	SWAB	WATER	SOIL		FORM	ACETONE (ISOOCTANE	BETASAN;PREFAR;BETAMEC;R4461	pH 3-6
126	BIFENTHRIN	SWAB	WATER	SOIL		FORM	ACETONE/MeCl2	TALSTAR; BRIGADE	
157	BCMYL	SWAB					ACETONE/ETHANOL	FLY BAIT GRITS	
92	BORON; BORATES; BORIC ACID				DUST		AA / ICP	BORIC ACID	
63	BROMACIL	SWAB		SOIL			METHANOL	BROMACIL; HYVAR X	pH 7-9
73	CAPTAFOL	SWAB	WATER	SOIL		FORM	HEXANE	DIFOLATAN	
72	CAPTAN	SWAB	WATER	SOIL			HEXANE	ORTHOCIDE; CAPTAN	pH 2-4
21	CARBARYL	SWAB	WATER	SOIL			METHANOL	CARBARYL;SEVIN;SAVIT;SEVIMOL	pH 3 *****
23	CARBOFURAN	SWAB	WATER	SOIL		FORM	METHANOL	FURADAN	pH 3-5
27	CHLORDANE	SWAB	WATER	SOIL	AIR		HEXANE	CHLORDANE;C-100; TERMIDE (MIX)	pH 3-6
	CHLOROBROMURON	SWAB						MALORAN	
101	CHLOROTHALONIL	SWAB	WATER	SOIL			ACETONE/XYLENE	BRAVO;DACONIL;(EXOTHERM)TERMIL	pH 3-8
2	CHLORPYRIFOS	SWAB	WATER	SOIL	AIR		HEXANE	DURSBAN;LORSBAN;EMPIRE;FURLOE	pH 3-4
309	CLOMAZONE (DIMETHAZONE)					FORM	METHANOL	COMMAND; COMMENCE*; (52)	
99	COPPER (CUPROUS/CUPRIC SALTS)						AA / ICP COPPER	COPPER SULFATE/HYDROXIDE/OXIDE	
57	CYANAZINE	SWAB					METHANOL*	BLADEX; EXTRAZINE (55)	pH 6-8
138	CYFLUTHRIN	SWAB	WATER	SOIL			HEXANE	TEMPO; BAYTHROID;LASER	pH 5-6
109	CYPERMETHRIN	SWAB	WATER	SOIL			HEXANE		pH 5-6
210	DALAPON	SWAB	WATER	SOIL				DALAPON; DOWPON	
175	DDD 4,4-	SWAB	WATER	SOIL			HEXANE		
176	DDE 4,4-	SWAB	WATER	SOIL			HEXANE		
177	DDT 4,4-	SWAB	WATER	SOIL			HEXANE		
	DEET					FORM	HEXANE/ACETONE	DEET POWDER FORMULATION	
178	DEMETON	SWAB	WATER	SOIL		FORM	HEXANE	SYSTOX	
3	DIAZINON	SWAB	WATER	SOIL	AIR		HEXANE	DIAZINON;SPECTRACIDE;KNOX OUT	pH 7 ***** P&A

PCP CODE	PESTICIDE Common Chemical Name	SAMPLE MATRIX Swab	Water	Soil	Air	Other	EXTRACTION SOLVENT	TRADENAME / SYNONYMS	STABILITY / STABLE pH RANGE
42	DICAMBA	SWAB	WATER	SOIL			MeOH/ETHER/ACID	BANVEL;	pH 2-8
14	DICHLORVOS (DDVP)	SWAB		SOIL	AIR		HEXANE	DDVP; VAPONA	pH 3-6 *****
98	DICOFOL (KELTHANE)	SWAB	WATER	SOIL		FORM	METHANOL	DICOFOL;KELTHANE	
184	DIELDRIN	SWAB	WATER	SOIL		FORM	HEXANE		pH 7-8
185	DIENOCHLOR		WATER	SOIL		Vegetation	HEXANE	PENTAC	
105	DIFLUBENZURON	SWAB					ACETONITRILE	DIMILIN; VIGILANTE	pH 3-6
96	DIMETHOATE	SWAB	WATER	SOIL		FORM	HEXANE	CYGON;DEFEND	pH 3-6
136	DINOSEB (DNBP)		WATER	SOIL			ACID	DINOSEB;DNBP;PREMERGE	pH 4-6
83	DIPHACINONE					FORM		RAMIK	
91	DIQUAT		WATER			FORM	Solid Phase Extraction	DIQUAT, AQUACIDE	
135	DIURON	SWAB	WATER	SOIL			METHANOL/MeCl2	DIURON; KARMEX; DIREX	
124	DORMANT OIL	SWAB				FORM	HEXANE		
120	DSMA (DISODIUM METHANE ARSENATE)						AA/ICP ARSENIC	ANSAR; DI-TAC; WEED-E-RAD	
199	EDB (ETHYLENE DIBROMIDE)	SWAB	WATER	SOIL			MeCl2 / HEXANE	DIBROME; BROMOFUME	
200	EDC (ETHYLENE DICHLORIDE)	SWAB	WATER	SOIL			MeCl2 / HEXANE	BROCIDE	
30	ENDOSULFAN, I, II; (ALPHA, BETA)	SWAB	WATER	SOIL			HEXANE	THIODAN;ENDOCIDE;TIOVEL;	pH 7
89	ENDOTHAL					FORM	Direct Injection of Liquid	AQUATHALL;ENDOTHALL	pH 3-6
193	ENDRIN	SWAB	WATER	SOIL			HEXANE	ENDRIX;HEXADRIN	pH 7-8
69	EPTC	SWAB					HEXANE	EPTAM;ERADICANE	pH 5-8
197	ETHION	SWAB	WATER				MeCl2	ETHION	
199	ETHYLENE DIBROMIDE (EDB)	SWAB	WATER	SOIL			MeCl2 / HEXANE	BROMOFUME; DIBROME	
200	ETHYLENE DICHLORIDE (EDC)	SWAB	WATER	SOIL			MeCl2 / HEXANE	BROCIDE	
	ETU (ETHYLENE THIOUREA)	SWAB				FORM	METHANOL	DEGRADATE OF EBDC'S;MANEB;ZINEB	
129	FENAMIPHOS	SWAB	WATER				HEXANE	NEMACUR	pH 6-7
137	FENOXYCARB	SWAB	WATER				METHANOL	TORUS	
38	FENVALERATE	SWAB	WATER	SOIL			ACETONE/HEXANE	PYDRIN; TRIBUTE; ASANA	pH 4-7
216	FOLPET	SWAB	WATER	SOIL			HEXANE	FOLPET; FOLPAN; PHALTAN	
71	GLYPHOSATE		WATER	SOIL		FORM	BUFFERS	RODEO;ROUNDUP;KLEENUP;	NONE
7	GUTHION (AZINPHOS-METHYL)	SWAB	WATER	SOIL			HEXANE	GUTHION	pH 7
	HCH ALPHA (BHC/HEXACHLOROHEXANE)	SWAB	WATER	SOIL		FORM	HEXANE/MeCl2		
	HCH BETA (BHC/HEXACHLOROHEXANE)	SWAB	WATER	SOIL		FORM	HEXANE/MeCl2		
31	HCH GAMMA (BHC / LINDANE)	SWAB	WATER	SOIL		FORM	HEXANE		
	HCH DELTA (BHC/HEXACHLOROHEXANE)	SWAB	WATER	SOIL		FORM	HEXANE		
28	HEPTACHLOR	SWAB	WATER	SOIL	AIR	FORM	HEXANE	TERMIDE, C-100	pH 4-6
106	HEPTACHLOR EPOXIDE	SWAB	WATER	SOIL	AIR	FORM	HEXANE	HEPTACHLOR DEGRADATED	
225	HEXAZINONE	SWAB		SOIL			METHANOL	VELPAR	
123	ISAZOFOS	SWAB	WATER			FISH	HEXANE	TRIUMPH	pH 3-6
1	ISOFENPHOS	SWAB	WATER	SOIL	AIR	FORM	HEXANE	PRYFON 6; OFTANOL; AMAZE;	pH 3-7
31	LINDANE (GAMA HCH)	SWAB	WATER	SOIL	AIR		HEXANE	ISOTOX	pH 3-6

NJDEPE LABORATORY ROUTINE CAPABILITY FOR PESTICIDE ANALYSIS

UPDATED 8/1/92 (PCP/TEAM/AMW)

PCP CODE	PESTICIDE Common Chemical Name	SAMPLE MATRIX Swab	Water	Soil	Air	Other	EXTRACTION SOLVENT	TRADENAME / SYNONYMS	STABILITY / STABLE pH RANGE
66	LINURON	SWAB	WATER				ACETONE	GEMINI; LOROX; LINEX	pH 7.0
8	MALATHION	SWAB	WATER	SOIL	AIR		HEXANE	MALATHION; CYTHION	pH 5.6 BUFFER
79	MANCOZEB					FORM	METHANOL	PENNCOZEB; DITHANE M-45;	*****
78	MANEB					FORM	METHANOL	MANEB; DITHANE; MANZATE; MANEX	*****
	MCPA (METHYLCHLOROPHENOXYACETIC	SWAB	WATER	SOIL		FORM	METHANOL	WEEDONE;	
43	MECOPROP; MCPP	SWAB	WATER	SOIL			MeOH/ETHER/ACID	TRIMEC(MCPP+24D+DICAMBA); CMPP	pH 2-8
25	MERCAPTODIMETHUR	SWAB					METHANOL/PCR	MESUROL	pH 3-5
102	METALAXYL	SWAB					METHANOL	SUBDUE P; RIDOMIL; APRON	
12	METHAMIDOPHOS	SWAB	WATER	SOIL			ACETONE	MONITOR; ACEPHATE MET	pH 4-6
234	METHANE ARSONIC ACID (MAA)						AA/ICP ARSENIC		
25	METHIOCARB	SWAB	WATER	SOIL			MeOH/MeCl2/PCP	MESUROL	
26	METHOMYL (LANNATE)	SWAB					METHANOL	LANNATE; NUDRIN	pH 4-6
32	METHOXYCHLOR	SWAB	WATER	SOIL			HEXANE	MARLATE	pH 3-6
6	METHYL PARATHION	SWAB	WATER	SOIL		FORM	HEXANE/MeCl2	PENNCAP-M	
45	METOLACHLOR	SWAB	WATER	SOIL			METHANOL	BICEP*; DUAL; PENNANT	pH 5-7
58	METRIBUZIN	SWAB	WATER	SOIL			METHANOL*	SENCOR; LEXONE; SALUTE*	pH 5-8
107	MEVINPHOS	SWAB					HEXANE	PHOSDRIN	pH 2-5
308	MGK 264	SWAB	WATER	SOIL			HEXANE	n-OCTYL BICYCLOHEPTENEDICARBOXIMIDE	
241	MONURON	SWAB	WATER	SOIL			METHANOL/MeCl2	UROX	
242	NALED	SWAB	WATER	SOIL			HEXANE/MeCL2	DIBROM	
308	n-OCTYLBICYCLOHEPTENEDICARBOXIMIDE	SWAB	WATER	SOIL			HEXANE	MGK 264	
123	OIL (DORMANT OIL)					FORM	ISOOCTANE	SCALECIDE; DORMANT OIL	
50	ORYZALIN	SWAB	WATER	SOIL			ACETONITRILE	SURFLAN; XL-2G; ROUT	
53	OXADIAZON	SWAB	WATER	SOIL			HEXANE	RONSTAR	pH 4-8
24	OXAMYL	SWAB	WATER	SOIL			METHANOL	VYDATE; THIOXAMYL	pH 3 *****
16	OXYDEPROFOS	SWAB					HEXANE	METASYSTOX-S	
90	PARAQUAT		WATER			FORM	Solid Phase Extraction	GRAMOXONE; PARAQUAT	pH 3-6
5	PARATHION (ETHYL)	SWAB	WATER	SOIL			HEXANE	(AQUA)PHOSKIL; PENNCAP-E	pH 3-6
6	PARATHION-METHYL	SWAB	WATER	SOIL			HEXANE	PENNCAP-M	pH 5-6
51	PENDIMETHALIN	SWAB					HEXANE/ACETONE	PROWL; HERBADOX; STOMP	
93	PENTACHLOROPHENOL (PCP)	SWAB	WATER	SOIL			HEXANE/MeCl2	PCP	
36	PERMETHRIN	SWAB	WATER				HEXANE	TORPEDO; DRAGNET; POUNCE; AMBUSH	pH 5-6
10	PHOSMET	SWAB	WATER	SOIL			HEXANE	PROLATE; IMIDAN	pH 3-6
34	PIPERONYL BUTOXIDE (PBO)	SWAB				FORM	HEXANE	PBO; BUTACIDE	pH 2-9
56	PROMETON			SOIL			METHANOL*	PRAMITOL, ORTHO TRIOX	pH 6-7
4	PROPETAMPHOS	SWAB	WATER	SOIL	AIR		HEXANE	SAFROTIN	pH 5-6
20	PROPOXUR	SWAB	WATER	SOIL			METHANOL	BAYGON	pH 3-7
33	PYRETHRIN	SWAB					HEXANE	CHRYSANTHEMATES (I); PYRETHRATES (II)	pH 5-6
133	QUATERNARY AMMONIUM (QUAT)					FORM	TITRATION	D-ALGAE; "QUAT"	

PCP CODE	PESTICIDE Common Chemical Name	Swab	SAMPLE MATRIX Water	Soil	Air	Other	EXTRACTION SOLVENT	TRADENAME / SYNONYMS	STABILITY / STABLE pH RANGE
37	RESMETHRIN	SWAB	WATER	SOIL			HEXANE	VECTRIN; SYNTHRIN	pH 5-6
272	RONNEL	SWAB	WATER	SOIL			HEXANE	KORLAN; DISC'D BY DOW	
100	ROTENONE	SWAB					ACETONITRILE	NOXFISH; ROTACIDE; CHEMFISH	
67	SIDURON	SWAB	WATER	SOIL			METHANOL/MeCl2	TUPERSAN	
59	SIMAZINE	SWAB					METHANOL*	AQUAZINE;PRINCEP;PRIMATOL S	pH 6-7
87	STRYCHNINE SULFATE (ALKALOID)	SWAB				STOM.	BUFFER	NUX VOMICA	pH 3
131	SULFOMETURON METHYL			SOIL			HEXANE	OUST	pH 7-9
68	TEBUTHIURON	SWAB					METHANOL	SPIKE	pH 6-8
18	TEMEPHOS	SWAB					HEXANE	ABATE	pH 6-8
	TETRADIFON		WATER	SOIL			METHANOL		
287	TETRAMETHRIN					FORM	HEXANE	NEO-PYNAMIN	
75	THIRAM	SWAB					METHANOL	SPOTRETE-F; SLUG-GETA; POLYRAM	******
52	TRIFLURALIN	SWAB	WATER	SOIL		FORM	MeOH; HEX/ACETONE	TREFLAN;TRILIN;TEAM*;SALUTE*	pH 3-8
81	WARFARIN					FORM	HEXANE / ACETONE	WARFARIN	
80	ZINEB					FORM	METHANOL	DITHANE Z 78	******

Pesticide Stability / Water Sample Stable pH Range Marked with *** Indicates that the Pesticide may be Unstable or Labile

***** -- Starred Pesticides Are Considered Unstable or Labile; They Should Be Analyzed On a Priority Basis

*****E&A -- EXTRACT AND ANALYZE AS SOON AS POSSIBLE!

AA / ICP -- Analysis Requires Atomic Absorption (Flame or Graphite Furnace AA) or Inductively Coupled Plasma (ICP) Spectroscopy

Appendix E.

1992 Supplement to the 1990

NATIONAL STANDARD PLUMBING CODE

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The National Association of Plumbing-Heating-Cooling Contractors

Chapter 13—Storm Drains

p. 13-1 *Amend* Section 13.1.5 - Subsoil Drains *to read*

"13.1.5 Subsoil Drains.

a. Subsoil Drains. Subsoil drains shall be provided around the perimeter of all buildings having basements, cellars, or crawl spaces or floors below grade. Such subsoil drains may be positioned inside or outside of the footings, and shall be of perforated, or open joint approved drain tile or pipe not less than 3" in diameter, and be laid in gravel, slag, crushed rock, *approved 3/4" crushed-recycled glass aggregate* or other approved porous material with a minimum of 4" surrounding the pipe on all side.

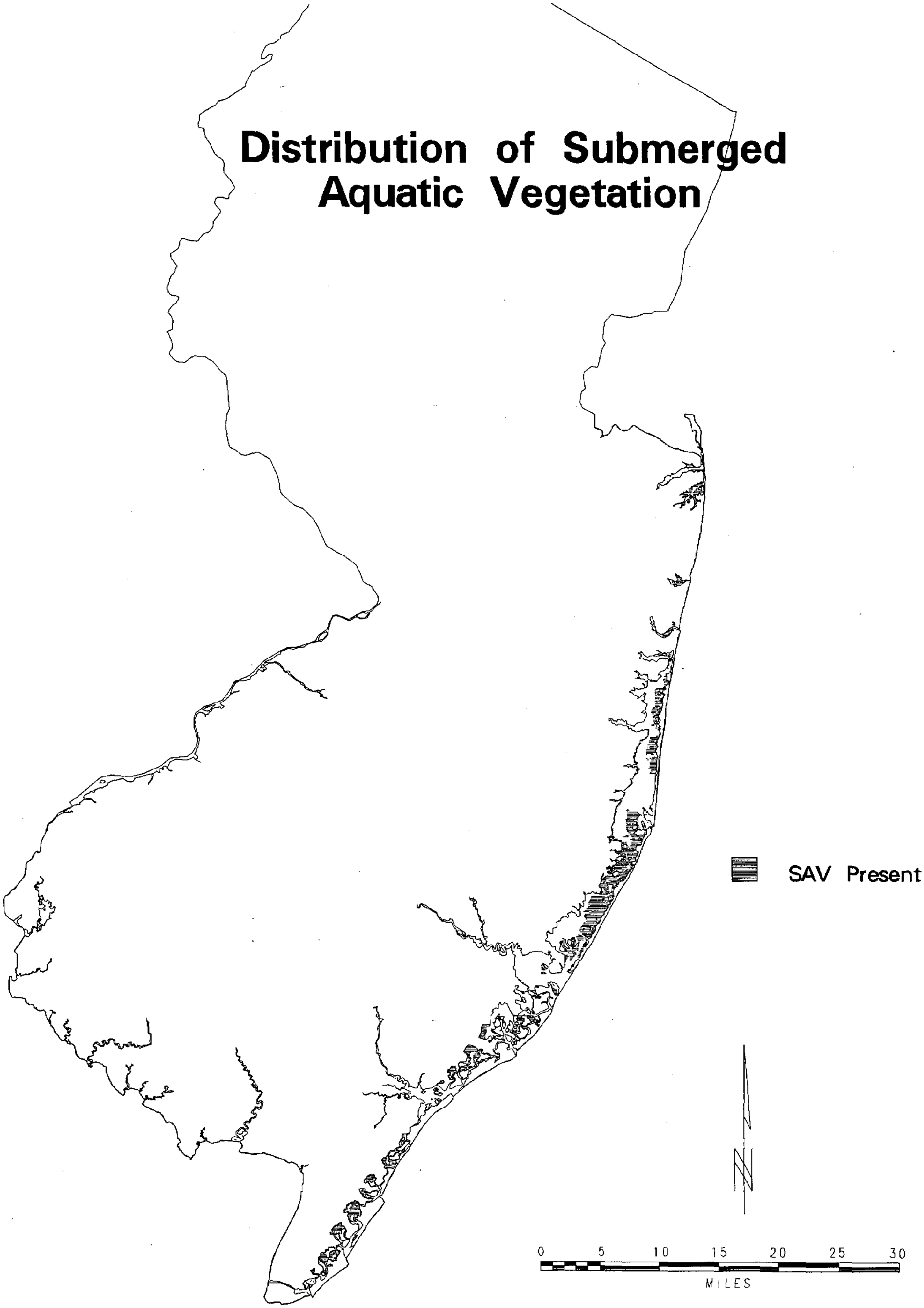
b. Sub-soil drains shall be piped to a storm drain, or to an approved water course, or to the front street curb or gutter, or to the alley, or the discharge from the sub-soul drains shall be conveyed to the alley by a concrete gutter. Where a continuous flowing spring or ground water is encountered, sub-soil drains shall be piped to a storm drain or an approved water course.

c. Where it is not possible to convey the drainage by gravity, sub-soil drains shall discharge to an accessible sump pit provided with an approved automatic electric pump. Sump pit shall be at least 15" in diameter, 18" in depth, and provided with a fitted cover. The sump pump shall have an adequate capacity to discharge all water coming into the sump as it accumulates to the required discharge point, and in no event shall the capacity of the pump be less than 15 gallons a minute. The discharge from the sump pump shall be a minimum of 1 1/4".

d. For separate dwellings, not serving continuous flowing springs or ground water, the sump pipe shall discharge onto a concrete splash block with a minimum length of 24". This discharge pipe shall be within 4" of the splash block and positioned to direct the flow parallel to the recessed line of the splash block.

e. Sub-soil drains subject to backflow when discharging into a storm drain shall be provided with a back-water valve in the drain line so located as to be accessible for inspection and maintenance.

f. Nothing in this regulation shall prevent the discharge of drains serving sub-soil drains, or areaways of detached buildings, which do not serve continuous flowing springs or ground water, from discharging to a properly graded open area, provided the point of discharge is at least ten (10) feet from any property line, where it is impracticable to discharge the drain or drains to the street gutter or curb, a storm drain, an approved water course, or to an alley.


Distribution of Submerged Aquatic Vegetation
SAV Present
N
0 5 10 15 20 25 30
MILES

10/93